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COLORADO SCIENTIFIC SOCIETY
PROCEEDINGS

VOLUME 11

1914-1923

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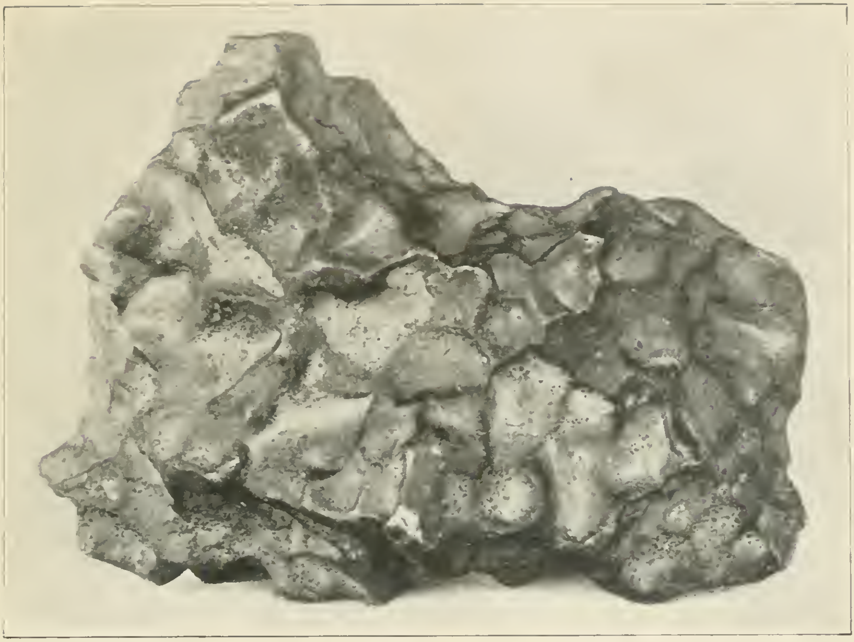
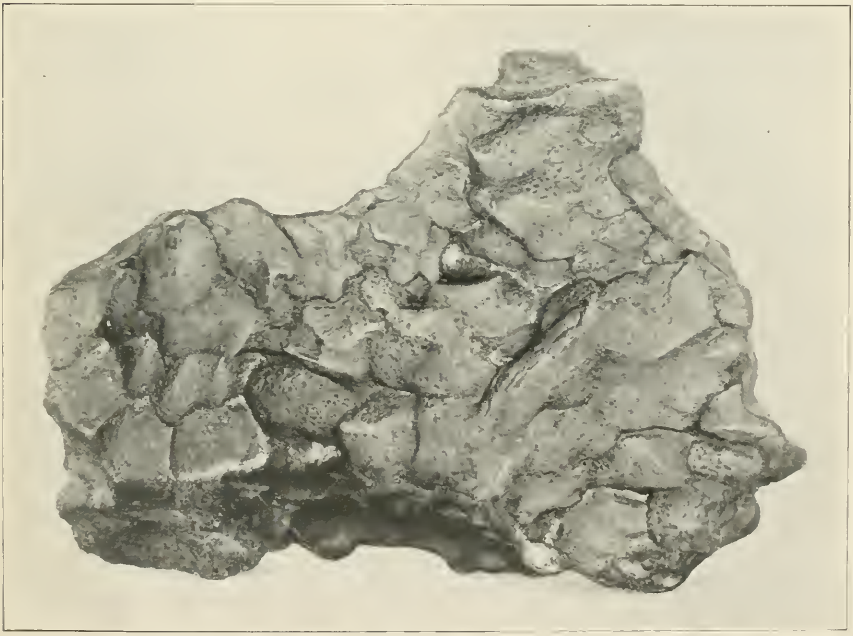


Plate I.



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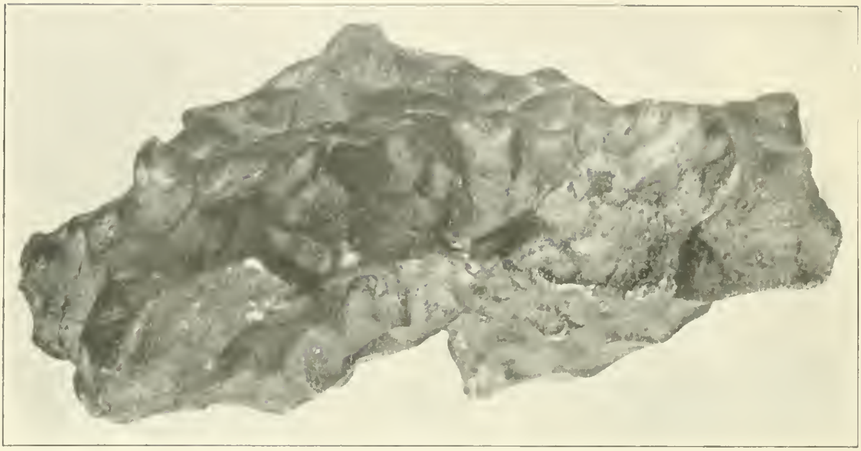
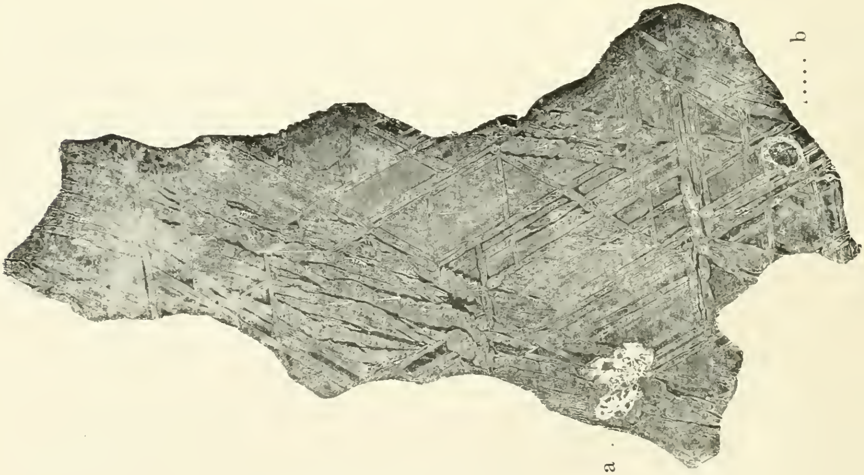


Plate III.



Glorieta Meteorite. Rio Arriba, N. M., Fall.
Printed from etched slice.

a. Grains of Olivine.
b. Grain of Troilite.

REPORT OF THE EXECUTIVE COMMITTEE OF THE COLORADO SCIENTIFIC SOCIETY FOR THE YEAR 1914.

The affairs of the Society have been administered throughout the year by the Executive Committee in the usual faithful manner. Acknowledgment is made of the assistance of many members in forwarding the interests of the Society, particularly in the matter of securing and moving into the new quarters. Specifically, we acknowledge the faithful co-operation of Mr. Franklin Guiterman and Mr. Otto Mears, as well as the generosity of the State Board of Capitol Managers. Formal acknowledgment has been made to these gentlemen for their valued services.

The most important event of the year, and perhaps in the history of the Society, was the acquisition of new quarters in the Colorado State Museum, erected by the Board of Capitol managers at the corner of Fourteenth avenue and Sherman street, opposite the Capitol. The Board of Capitol Managers generously granted our Society free use of commodious quarters in this new and beautiful building, which we have occupied since October 1, 1914. The library and mineral collection are placed in a large, beautifully decorated room, forty feet square. This room serves also as a large auditorium, and a smaller room is provided for the office of the assistant secretary and librarian.

In moving into these new rooms, the Executive Committee felt obliged to purchase some new furniture and fixtures in order that our possessions might harmonize with the beauty and dignity of the rooms. Money has been expended judiciously and for permanent improvements. Further expenditures remain to be made, and when all our plans are executed the Society will be favored with facilities for its work such as it has never had before. This beautiful and permanent home will be of immeasurable benefit, and will enable us to expend more money on library and publications, thereby increasing the value of the Society to the members.

The proceedings of the Society for the past year show that nine regular meetings were held, at eight of which papers were read. The February meeting was a joint meeting with the Colorado School of Mines, held at Golden, Colorado, at which Professor William M. Davis, of Harvard University, delivered a lecture on "The History of the Front Range." There were four papers printed during the year.

The average attendance for the nine meetings was 23. The lowest attendance at any meeting was 12 in April while the highest was 35 in September. In 1913 the lowest attendance at any regular meeting was 8 in December, while the highest was 35 in April.

During the year 10 members have been elected. The loss has been 15: three by death, 11 by resignation and one dropped by action of the Executive Committee. Those lost by death were Mr. Walter C. Brace, who died in Syracuse, New York, in August, 1914; Mr. Godfrey D. Doveton, who died in Guadalajara, Mexico, January 20th, 1914, and Mr. Henry C. Lay, who died at his home, Mansfield Apartments, Telluride, Colo., June 8th, 1914. The net loss in membership was five.

Of the present total membership of 233: 142 reside in Denver, 43 outside of Denver in Colorado, 41 outside of Colorado in the United States and seven in foreign countries. The roll consists of six Life Members, 10 Honorary Fellows, 10 Fellows, 179 Members and 28 Associates.

There have been five Exchanges added during the past year, viz.: School of Mines, Department of Mining and Metallurgy, Queen's University, Kingston, Ontario; Johns Hopkins University Library, Baltimore, Maryland; University of Minnesota Library, Minneapolis, Minnesota; Missouri State Historical Society, Columbia, Missouri, and Pennsylvania State Museum, Harrisburg, Pennsylvania.

Accessions to the Library during 1914 were as follows:

By Purchase—

American Electrochemical Society Transactions, Volumes 24 and 25.

Copper Hand Book, Volume XI, 1912-13.

Mineral Industry During 1913, Volume 23.

Tables Annuelles Internationales De Constantes et Donnees Numeriques.

By Gift—

American Institute of Electrical Engineers, Volume 31, complete. Presented by Mr. Charles W. Comstock.

American Institute of Metals, Transactions, Volume 7, 1913.

American Institute of Mining Engineers Transactions, Index to Volumes 21-25. Presented by Mr. Harry W. Robinson.

American Institute of Mining Engineers, Bulletin Numbers 77, 84, 85, 86 and 87. Presented by Mr. E. Le Neve Foster.

American Society of Civil Engineers, Volume 39, Numbers 7, 8, 9 and 10; Volume 40, Numbers 1, 2, 3 and 4, and Paper Number 1268. Presented by Mr. Thomas L. Wilkinson.

American Society of Mechanical Engineers, Volume 35, Numbers 10, 11 and 12, and Journals for Jan., Feb., March, April and May, 1914. Presented by Mr. Thomas L. Wilkinson.

Bureau of American Ethnology, Bulletin Number 56.

California State Mining Bureau, Eighth and Twelfth Annual Reports of the State Mineralogist; also Bulletin Number 66, "Mining Laws." Presented by Mr. F. McN. Hamilton, State Mineralogist.

Chemical Society of London: Journal Volumes 103 and 104, Numbers 611, 613 and 614, and Index, Volumes 105 and 106, Numbers 615, 616, 617 and 618. Proceedings Volume 29 Numbers 420-428, inclusive, and Index. Presented by Mr. S. A. Ionides.

Complete Mineral Catalogue, by Mr. W. M. Foote.

Colorado Scientific Society Proceedings, Volume 4. Presented by Mr. Harry W. Robinson.

Geological and Natural History Survey of Wisconsin, Bulletin Number 27.

Illinois State Geological Survey, Bulletin Number 22, and Maps for same. Presented by Mr. H. C. Parmelee.

Interstate Commerce Commission, Twenty-seventh Annual Report, 1913.

Iowa Academy of Science, Proceedings Volume 20, 1913.

Iowa Geological Survey, Annual Report, Volume 24, also Bulletin No. 4.

Library of Congress, Report for 1913.

Michigan Academy of Science, Fifth Report, 1913.

Minerals of California, Bulletin Number 67.

Mineral Resources of the United States for 1912, Parts 1 and 2.

Ore Dressing by Robert H. Richards, Volumes 3 and 4, also Index to Volumes 1, 2, 3, and 4. Presented by Mr. Edward S. Wiard.

The Indians of Pikes Peak Region by Irving Howbert. Presented by the Author.

The Railway Library and Statistics, 1913.

United States National Museum; Proceedings Volume 45, Bulletin Number 46, and Annual Report for 1913.

H. C. Parmelee,
Secretary.

REPORT OF THE TREASURER OF THE COLORADO SCIENTIFIC SOCIETY FOR THE YEAR ENDING DECEMBER 19TH, 1914.

Receipts.

Balance from Statement of 1913	$ 144.30	
Annual Dues	1,360.00	
Advanced by Members to meet expense in furnishing New Rooms	300.00	
Annual Dinner	213.50	
Sales of Old Furniture	11.70	
Sale of Publications	6.35	
		$2,035.85

Disbursements.

Rent	$ 450.00	
Salary of Assistant Secretary	365.00	
Printing Notices, Ballots, Stationery, etc.	91.70	
Printing Proceedings	143.65	
Postage and Envelopes	67.92	
Library—Books and Magazines	136.25	
Library—Book Cases	209.00	
Lecture Room—Chairs and Desks	139.50	
Illustrating Lectures	20.00	
Annual Dinner	213.82	
Telephone	36.40	
Petty Cash	37.50	
Miscellaneous Supplies	1.50	
Exchange	1.35	
Moving Expenses	40.00	
Cash on Hand	82.26	
		$2,035.85

Respectfully submitted,

J. W. Richards,
Treasurer.

Attest:

Frank E. Shepard,
M. B. Holt,
H. B. Lowden,
Auditing Committee.

ANNUAL REPORT OF THE SECRETARY OF THE COLORADO SCIENTIFIC SOCIETY, DECEMBER 18TH, 1915.

The Proceedings of the Society for the past year show that nine regular meetings were held, at eight of which papers were read, the program of the September meeting being a general discussion. The papers read and the subjects of discussion were as follows:

"The Distribution of the American Indians," by Dr. Livingston Farrand.

"The Relation of Chemistry to Agriculture," by Dr. William P. Headden.

"The Triumphs of Preventive Medicine," by Dr. J. W. Amesse.

"Centrifugal Pumps, Their History and Development," by Mr. Albert E. Guy.

"The Commercialization of the Chemical Reaction," by Dr. Herman Fleck.

"The Rare Metals," viz.: "Tungsten," by Dr. Herman Fleck.

"The Present Status of Wireless Telegraphy," by Prof. Oliver C. Lester.

"The Rare Metals," viz.: "Molybdenum," by Dr. Herman Fleck.

"Discussion," "The Flotation Process," Messrs. Fred Carroll, James M. McClave, Bradish P. Morse and Albert M. Plumb.

There were two papers published during the year, being, "The Triumphs of Preventive Medicine," by Dr. J. W. Amesse, and "Genesis of the Centrifugal Pump," by Mr. Albert E. Guy.

The average attendance for the nine regular meetings was 49. The lowest attendance at any meeting was 25 in June, while the highest was 87 in February. In 1914 the lowest attendance at any regular meeting was 12 in April, while the highest was 35 in September.

During the past year two members have been elected. The loss has been 25; 2 by death, 15 by resignation, and 8 were dropped from the Membership list by action of the Executive Committee. Those lost by death were Mr. Franklin L. Clerc, who died at the Shirley Hotel in Denver, Colorado, on March 12th, 1915, and Mr. Franklin Guiterman, who died at his home in New York City on May 9th, 1915. The net loss in membership this year was 23, while last year it was 5.

Of the present total membership of 210; 131 reside in Denver, 36 outside of Denver in Colorado, 39 outside of Colorado in the United States, and 4 in foreign countries. The Membership Roll consists of 6 Life Members, 9 Honorary Fellows, 9 Fellows, 161 Members and 25 Associates.

There were no additions to the Exchange List during the year.

A number of books and periodicals have been added to the Library during the past year, some by purchase, some by gift from the members and some by gift from those who are not members but are interested in the work of the Society.

HOWARD C. PARMELEE, *Secretary.*

REPORT OF THE TREASURER OF THE COLORADO SCIENTIFIC SOCIETY FOR THE YEAR ENDING DECEMBER 18TH, 1915.

RECEIPTS.

Balance from Statement of 1914	$ 82.26	
Annual Dues	1,270.00	
Annual Dinner	276.50	
Franklin Guiterman Donation	100.00	
Sale of Proceedings	4.00	
Sale of Old Furniture	1.00	
		$1,733.76

DISBURSEMENTS.

Salary of Assistant Secretary	$ 365.00	
Printing Notices, Ballots, Stationery, etc.	61.15	
Printing Proceedings	192.75	
Postage and Envelopes	60.00	
Library—Books and Magazines	34.00	
Library—Bookcases	55.00	
Annual Dinner	232.25	
Moving Expenses	91.80	
Telephone	36.26	
Balopticon and Accessories	49.30	
Money Advanced by Members During 1914 to Help Defray Expenses of Moving	300.00	
Petty Cash	30.00	
Fire Insurance	24.00	
Museum	66.50	
Lecture Expenses	10.50	
Taxes	3.27	
Exchange on Checks	.75	
Miscellaneous	4.00	
		$1,616.53
Cash on Hand		$ 117.23
		$1.733.76

Respectfully submitted,

J. W. RICHARDS,

Treasurer.

ANNUAL REPORT OF THE SECRETARY OF THE COLORADO SCIENTIFIC SOCIETY, DECEMBER 16TH, 1916.

The Proceedings of the Society for the past year show that nine regular meetings were held, at which ten papers were read and two evenings given to general discussions of important subjects. The papers read and the subjects of discussion were as follows:

"Munitions," "Chemistry and Manufacture of Explosives," by Mr. S. S. Emery.

"Ordnance," "The Use in Military Operations," by Major J. B. Goodman.

"The Rare Metals," viz.: "Vanadium," by Dr. Herman Fleck.

"The Low-Temperature Distillation of Lignite," by Mr. Charles O. Hoover.

"The Rare Metals," viz.: "Uranium," by Dr. Herman Fleck.

"Development of Transcontinental Telephone Service," by Mr. George Spaulding.

"Mineralological Notes, No. IV," by Dr. William P. Headden.

"Some Analytical Notes on Titanium, Columbium, Tantalum and Zirconium," by Dr. William P. Headden.

"Some Rare Minereal Occurrences, Including Galena with Octahedral Cleavage," by Mr. Richard C. Hills.

"A Denver-Made Spinthariscope for Counting the Helium Atoms Given Off by Radioactive Preperations," by Mr. Richard C. Hills.

Discussion, "Smoke Abatement."

Discussion, "The Revision of the Mining Law."

There were four papers published during the year, under one cover, being "A Series of Treatises on the Rare Metals," by Dr. Herman Fleck, these papers having been read at four different meetings of the Society.

The average attendance for the nine regular meetings was 40 1/9. The lowest attendance at any meeting was 18 in November, while the highest was 102 in February. In 1915 the lowest attendance at any regular meeting was 25 in June, while the highest was 87 in February.

During the year 6 members have been elected. The loss has been 9; 2 by death, 5 by resignation and 2 dropped from the Membership List by action of the Executive Committee. Those lost by death were Mr. William L. Sclater, the date of whose death we do not know, and Dr. Lucien I. Blake, who died in Boston, Massachusetts, May 4th, 1916. The net loss in membership this year was 3, while last year it was 23.

Of the present total membership of 207, 127 reside in Denver, 39 outside of Denver in Colorado, 39 outside of Colorado in the United States, and 2 in foreign lands. The roll consists of 6 Life Members, 8 Honorary Fellows, 9 Fellows, 158 Members and 26 Associates.

Two Exchanges have been added to the Exchange List during the past year.

A number of books and periodicals have been added to the Library during the past year, some by purchase, some by gift from members and some by gift from those who are not members but are interested in the work of the Society.

SIEGFRIED FISCHER, JR., *Secretary.*

REPORT OF THE TREASURER OF THE COLORADO SCIENTIFIC SOCIETY FOR THE YEAR ENDING DECEMBER 16TH, 1916.

Your Treasurer herewith begs to present his report for the year ending December 16th, 1916.

Receipts.

Balance from Statement of 1915	$ 117.23	
Annual Dues	1,270.00	
Annual Dinner	185.50	
Donation for Miscellaneous Expenses	25.00	
Sale of Publications	1.00	
		$1,598.73

Disbursements.

Salary of Assistant Secretary	$ 500.00	
Printing of Notices, Ballots, Stationery, etc.	60.10	
Printing of Proceedings	156.25	
Postage and Envelopes	75.00	
Library—Books and Magazines	58.50	
Annual Dinner	169.99	
Telephone	37.40	
Petty Cash	30.00	
Repairs to Show Cases	6.00	
Purchase of Typewriter	37.50	
Exchange on Checks	1.20	
Taxes	3.94	
Mineral Collection	5.00	
Miscellaneous	27.50	
		$1,168.38
Cash on Hand		$ 430.35
		$1.598.73

Respectfully submitted,

J. W. Richards,

Treasurer.

ANNUAL REPORT OF THE SECRETARY OF THE COLORADO SCIENTIFIC SOCIETY, DECEMBER 15TH, 1917.

The Proceedings of the Colorado Scientific Society for the past year show that five regular meetings were held at which seven addresses were given, as follows:

"Some Recent Results of the Enforcement of the Food and Drug Act," by Mr. R. S. Hiltner.

"Sanitation and the Public Food Supply," by Dr. George W. Stiles.

"Preparedness from an Engineering Point," by Mr. Richard A. Parker.

"Highway Construction and Maintenance from its Financial Side," by Mr. Leonard E. Curtis.

"The Kern Country," by Professor George J. Young.

"A Discussion of Different Kinds of Lead and Other Non-Separable Elements," by Dr. S. C. Lind.

"The Chemistry of the Proteins," by Dr. John B. Ekeley.

There were four papers published during the year, under two covers, being: "Mineralogical Notes No. IV, The Identity of Black Rutile and Strueverite" and "On the Estimation and Separation of Titanium, Columbium, Tantalum and Zirconium," by Dr. William P. Headdon, both of which were read at the meeting on November 4th, 1916; and "Notes on Rare Mineral Occurrences" and "A Denver Made Spinthariscope," by Mr. Richard C. Hills, these two papers having been read at the meeting of December 2nd, 1916.

The average attendance at the five regular meetings was 22 1/5. The lowest attendance at any meeting was 9, in May, while the highest was 35, in February. In 1916 the lowest attendance at any regular meeting was 18, in November, while the highest was 102, in February.

During the past year one member has been elected. The loss has been 13; 6 by death, 6 by resignation, and 1 dropped from the membership list by action of the Executive Committee. Those lost by death were: Mr. Hugh C. Browne, the time and place of whose death we do not have; Mr. O. F. Cary, who died at his home, 1515 East Eighth Avenue, Denver, on August 20th, 1917; Mr. Anton Eilers, who died at his home in Sea Cliff, Long Island, on April 21st, 1917, after a prolonged illness; Professor Arthur Lakes, who died at Nelson, B. C., on November 21st, 1917; Mr. T. E. Schwarz, who died at his home in Brookline, Massachusetts, on September 30th, 1917, and Dr. William S. Ward, who died at his home, No. 4 Tuxedo Place, Denver, on May 25th, 1917, after an illness of many months. The net loss in membership during this year was 11, last year it was 3.

Of the present total membership of 195; 112 reside in Denver, 40 outside of Denver in Colorado, 39 outside of Colorado in the United States and 4 in foreign lands. The roll consists of 6 Life Members, 8 Honorary Fellows, 9 Fellows, 147 Members and 25 Associates.

Two Exchanges have been added to the Exchange List during the past year.

A number of books and periodicals have been added to the Library during the past year, some by purchase, some by gift from members of the Society, and some have been the gift of those who are not members but are interested in the work of the Society.

The Executive Committee of the Society held five meetings during the year, at which matters concerning the welfare of the Society were considered.

In the absence of the Secretary, this report is respectfully submitted by

Rebecca M. Riddle,
Assistant Secretary.

REPORT OF THE TREASURER OF THE COLORADO SCIENTIFIC SOCIETY FOR THE YEAR ENDING DECEMBER 15TH, 1917.

Your Treasurer herewith begs to present his report for the year ending December 15th, 1917.

Receipts.

Balance from Statement of 1916	$ 430.35	
Annual Dues	1,215.00	
Annual Dinner	159.00	
Sale of Publications	21.00	
		$1,825.35

Disbursements.

Salary of Assistant Secretary	$ 540.00	
Library—Books and Magazines	107.00	
Printing Transactions	67.90	
General Printing	29.75	
Telephone	38.55	
Annual Dinner	139.15	
Petty Cash	30.00	
Postage	20.00	
Postage and Envelopes	45.00	
Freight on Books	18.23	
Mineral Collection	25.00	
Lantern Attachment	13.50	
Taxes	3.40	
Exchange on Checks	2.20	
Lectures	6.00	
		$1,085.68
Cash on Hand December 15th, 1917		739.67
		$1,825.35

Respectfully submitted,

J. W. Richards,

Treasurer.

Attest:

M. B. Holt.

J. Claire Evans.

Auditing Committee.

REPORT OF THE SECRETARY OF THE COLORADO SCIENTIFIC SOCIETY FOR THE YEAR ENDING DECEMBER 21ST, 1918.

Mr. President and Members of the Colorado Scientific Society:

During the year the Society held one Special Meeting and two Dinner Meetings. The Special meeting was called for the purpose of discussing and laying plans for the year. On account of war conditions, and the growing sentiment against meetings which were not essentially directed toward the winning of the war, it was considered advisable to replace the usual twelve regular monthly meetings by four dinner meetings, and to secure for each of these dinner meetings a prominent speaker who would deliver an address on some appropriate scientific subject which would be of interest to the general public.

The first dinner meeting was held on March 9th, at the Shirley Hotel. Following the dinner, Mr. H. E. Hilts, General Manager of the Portland Cement Association of Chicago. delivered an illustrated lecture on "The Construction and Use of Concrete Ships." Over 150 members and guests attended the meeting.

The second dinner meeting was held on May 28th, at the Daniels & Fisher Tea Room. Following the dinner Dr. Edwin B. Frost, Professor and Head of the Department of Astronomy and Astrophysics of the University of Chicago, and Director of the Yerkes Observatory, delivered an illustrated address on "Our Growing Appreciation of the Magnificence of the Stellar Universe." Over 250 members and guests attended the meeting.

Arrangements were made to hold two additional dinner meetings during the fall and winter, but these plans were interrupted by the epidemic of Spanish Influenza, and the subsequest orders which prohibited the holding of public meetings.

The Society published no papers during the past year, owing to the request of the Government for the conservation of materials. However, the Publication Committee has in hand and ready for publication five interesting and valuable papers, which will be distributed among the members in the near future.

The membership of the Society is at present 187. The membership is classified as to residence as follows: In Denver, 106; outside of Denver in Colorado, 39; outside of Colorado in the United States, 40; in foreign countries, 2. The membership list includes 8 Honorary Fellows; 9 Fellows; 5 Life Members; 142 Members; and 23 Associates. During the year 4 members were lost by death, and 4 by resignation. The members lost by death were: Mr. Fred T. Williams, of Salt Lake City, the date of whose death we do not have; Mr. Auguste Mathez, of Denver, who died February 4th, 1918; Mr. Lucius S. Pierce, of Denver, who died May 26th, 1918; and Dr. Wilbur A. Hendryx, of Allentown, Pa., who died September 21st, 1918.

During the year the Library received a number of new books and periodicals, some by purchase, some by donation from members, and others by donation from non-members interested in the work of the Society.

During the period under review the Executive Committee held seven meetings for the discussion of matters concerning the welfare of the Society.

Now that the war is over, and likewise its urgent demands upon the time and energies of the members of the Society, our officers anticipate a year of redoubled activity and usefulness. Several members have already promised to prepare and read papers during 1919. Every member who is willing to present a paper before the Society is urged to communicate with the Secretary at once, and if possible designate the title of his paper, and the date when it will be ready for presentation. As the usefulness of a Society like ours depends on the activity and co-operation of its members, it is to be hoped that the responses to this appeal will be so eager that the Secretary will be compelled to request many of the members to accept a postponement of the date of presentation of their papers.

Yours respectfully,
HARRY J. WOLF,
Secretary.

December 21st, 1918.

Your Treasurer herewith begs to present his report for the year ending December 21st, 1918.

Receipts.

Balance from Statement of 1917	$ 739.67	
Annual Dues	1,190.00	
Annual Dinner	96.00	
Lectures and Dinners	359.50	
Sale of Publications	4.25	
		$2,389.42

Disbursements.

Library Fixtures	$ 79.20	
Library—Books and Magazines	43.00	
Dinner and Lecture	150.00	
Dinner and Lecture	195.00	
Annual Dinner	98.50	
Lecture Expenses, Hilts	7.50	
Lecture Expenses, Frost	13.35	
Lecture Expenses, Swanson and Nolan	8.50	
Music, Annual Dinner	6.00	
General Printing	56.75	
Postage	22.40	
Postage and Envelopes	51.09	
Petty Cash	19.25	
Salary of Assistant Secretary	625.00	
Telephone for 1918	45.22	
Fire Insurance	30.00	
Taxes	4.00	
Exchange on Checks	1.20	
		$1,455.96
Cash on Hand December 21st, 1918		933.46
		$2,389.42

Respectfully submitted,

J. W. Richards,
Treasurer.

Attest:
Harry J. Wolf.
J. C. Roberts.
Auditing Committee.

PROCEEDINGS OF THE COLORADO SCIENTIFIC SOCIETY
VOL. XI, pp: 1-4.

ON A PROBABLE EIGHTH FRAGMENT OF THE GLORIETA METEORITE.

By RICHARD C. HILLS.

(Read at the meeting of the Society, September 6, 1913.)

On July 10th, 1912, on behalf of the Colorado Museum of Natural History, the writer purchased from Mr. H. Schweizer, Manager of the Fred Harvey Indian Curio Store at Albuquerque, New Mexico, a small meteorite said to have been obtained from a Mexican who reported that the specimen was found somewhere in Rio Arriba County in the same State. Unfortunately, Mr. Schweizer has no record of the name and address of the Mexican who sold him the meteorite. Hence, it is impossible to obtain more explicit information in regard to it. However, the crystalline structure, as revealed by the etched surface, and the presence of a limited amount of olivine, suggests very strongly that it is related to the well-known Glorieta Meteorite, though evidently not one of the fragments of that particular fall.

The Glorieta Meteorite was first described by George F. Kunz,* who figured three large fragments weighing in the aggregate, 317 pounds (143·76 kilos). Mr. Kunz gives the probable date of the find as May (?), 1884, and stated that the three sundered fragments were found lying on a rock buried about ten inches in the soil covering the rock. He classes the iron with the holosiderites of Danbrée and described it as "exhibiting characteristic octahedral structure, the Widmannstätten figures being made up of kamacite (balkeneisen or beam iron), i. e., iron with little nickel, enveloped in tænite (bandeisen), rich in nickel, and plessite (fülleisen). * * * The tænite was abundant and brilliant. * * * Troilite was observed in several places on the crust, also traces of olivine and perhaps schreibersite."

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*Am. Jour. Sci., Third Series, Vol. XXX, pp. 235-238, 1885.

An analysis by James B. Mackintosh is as follows:

Fe	87·93
Ni	11·15
Co	0·33
P	0·36
	99·77

Carbon, sulphur and other constituents were not determined. The following year Mr. Kunz published a second paper on the same iron.* He records the finding of three additional fragments by Mr. J. H. Bullock after six weeks digging. These three fragments were of comparatively small size, aggregating but 3·370 kilos. In describing a large cutting from mass No. 1, Mr. Kunz states that troilite appears in large patches and that schreibersite and olivine were present also. He likewise remarks on the raised octahedral structure shown on the disrupted surfaces.

On Oct. 6, 1884, Mr. Richard Pearce presented this Society with a small piece of a meteorite which before cutting weighed about 2·5 kilograms. This iron was sent to the Boston and Colorado Smelting Co. from Albuquerque, N. M., as silver bullion. No additional information could be obtained in regard to it.

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*Am. Jour. Sci., Third Series, Vol. XXXII, pp. 311-313, 1886.

On June 1, 1885, Mr. L. G. Eakins read a short paper before this Society on the same meteorite in which he gives the following analysis:

Fe	88·760
Ni	9·860
Co	0·510
Cu	0·034
Zn	0·030
Cr	Trace
Mn	Trace
C	0·410
P	0·182
S	0·012
Si	0·044
	99·842

In the second paper, Mr. Kunz remarks on the "striking similarity between this analysis and that of the Glorieta Meteorite" and expresses the belief that the Pearce iron is the seventh fragment of the Glorieta Meteorite which was found and carried off by a Mexican.

The meteorite, which is the subject of this paper, weighed before cutting 2·574 kilograms. The three dimensions are, respectively, 15·5 cm., 11·5 cm. and 7·0 cm. The form is shown in plates I, II and III, somewhat smaller than the natural size.

The pitting on the surface is angular instead of rounded, which Mr. W. M. Foote remarks is rare among irons, but is a characteristic of the Glorieta. Minute lines of flow are also observable. The crystalline structure revealed by the Widmannstätten figures on an etched surface is coarsely octahedral, as appears in Plate IV, which is printed direct from an etched slice. The most noteworthy feature is the numerous bright lines of tænite, the broad bands of kamacite and the presence of numerous shreds and crystalline patches of schreibersite embedded in the plessite or groundmass. Troilite is also present in nodules bordered by schreibersite and that in turn by plessite. Grains of olivine appear in all but one of six slices. It is yellowish-green to olive-green and always partly or wholly surrounded by troilite; the two being entirely surrounded by schreibersite and plessite.

The following analysis of a sample of the iron from which all traces of schreibersite were carefully excluded, was made by Asst. Professor H. H. Curtis of Colorado University.*

Fe	92·66
Ni	7·83—8·04
Co	Trace
	100·49

Tests were made for manganese, copper, arsenic, calcium, magnesium, silica and platinum, without results. On account of the careful exclusion of schreibersite, there was no reaction for phosphorus. In this respect the analysis of Prof. Curtis differs from those made by Eakins and Mackintosh, but the difference is explainable. The difference in the iron and nickel percentages can also be explained on the ground of variation in the respective amounts of tænite and kamacite entering into the samples. The absence of small quantities of copper, manganese, silica, etc., and their presence in the analysis by Eakins and referred to by Mackintosh, is not easy to explain unless these substances exist as impurities in the schreibersite, as several analyses of this mineral indicate. It will not be out of place here to urge greater care in the selection of meteorite samples for analysis.

In conclusion it may be said that the structural and mineralogical evidence, the pitting of the surface and the locality of the purchase, and careful comparison with a number of slabs of Glorieta in the American Museum, kindly made by Mr. Foote at my request, all point strongly to the identity of this iron with the Glorieta fall.

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*Average of five determinations.

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RECENT PROGRESS IN COLORADO PALEONTOLOGY AND STRATIGRAPHY.

By JUNIUS HENERSON.

Read at the meeting of the Society October 3, 1914.

One is not supposed to offer an apology to an audience for appearing before it without sufficient preparation, because one is not expected to so appear. Under the circumstances, however, I feel that I owe both the audience and myself an explanation of the reason for the unfinished and perhaps not well arranged character of the present address. I had not expected until a few days ago to appear on the program at this time, but was asked to do so because of an unexpected vacancy. A desire to be accommodating has led me to comply, at the risk of presenting the subject in a rather crude way, and possibly choosing unwisely in the selection of items of importance or interest, in the haste of preparation.

PRINCIPLES OF STRATIGRAPHY.

Before beginning a discussion of the subject announced, it may be well to recall some fundamental facts and principles which are perhaps more or less familiar to all. In order to fully comprehend the significance of paleontologic and stratigraphic progress, it is quite necessary to bear in mind the exact relation of paleontology to geology and biology.

The zoologist or botanist would hardly feel thoroughly acquainted with animal or plant life without first acquainting himself with the history of its developement, and that history can only be ascertained by a study of fossil forms occurring in successive strata. The student of evolution must necessarily draw his larger concrete illustrations chiefly from the realm of paleontology. Hence paleontological progress from a biological point of view would include any discovery which throws light upon the historical development of plants or animals or their relations to each other.

It would be quite possible for a geologist to construct some sort of a usable map of a limited area showing the surface distribution of sedimentary formations, without the aid of paleontology. In most regions, however, no geologist would hope to do a really thorough piece of mapping of sedimentary formations without recourse to the facts and principles of this science. In the correlation of formations in widely separated regions the fossils contained are absolutely indispensible. Even in a small area, a limestone, or sandstone or shale of Cretaceous or Carboniferous age may have exactly the same chemical composition and physical characteristics as one of Ordovician age, so that from an examination of the rock itself no one could determine its geologic age, but the fossils of these ages are entirely distinct, so that access to the fossils would be the only certain and final test. Where exposures of rock in place are few and small, the necessity of fossils for the correct determination of the age of formations and their positions in the stratigraphic column is greatly increased.

COLORADO FORMATIONS.

In Colorado formations we have all the geologic ages represented except one. The Archeozoic Era is well represented by the Archian granites, etc., and more sparingly by Algonkian schists. The Paleozoic Era is represented by small areas of Cambrian, larger areas of Ordovician and Devonian, and still larger areas of Carboniferous, including both the Mississippian and Pennsylvanian members, with considerable areas of strata which are possibly Permian, more generally here called Permo-Carboniferous. The Mesozoic Era presents the Dolores and probably other formations of the Triassic;

the Sundance, Morrison, La Plata, McElmo, Gunnison, and other formations of the Jurassic, aggregating a very large area; while an even greater area is occupied by various Cretaceous formations. The Cenozoic Era is represented by very extensive areas of Tertiary, with some Pleistocene and the recent alluvials. The Silurian Age, of the Paleozoic Era, alone seems to be unrepresented. The Paleozoic and Cretaceous formations are almost entirely of marine origin, the Jurassic (except Sundance), Triassic, Tertiary and Pleistocene are of fresh water and æolian origin.

Because of the immense periods of time represented, and the wide-spread occurrence of both marine and non-marine formations, there should be great opportunities for paleontological investigation and research. Unfortunately, however, there have been very few people in Colorado who have either the training for or the interest in such work. There are notable exceptions, but it would be out of place to mention names except in a casual way in referring to discoveries, as it is impractical to mention all who have contributed to final results, and there is no sharp line between the notable work and that which is not so noteworthy.

The Dinosaurs.

Probably the most spectacular paleontological discovery in Colorado was that of the immense reptiles in the Morrison and equivalent beds. The dinosaurs are better known to the general public than any other group of our fossils. Though for some time there was great activity in this line, especially at Morrison and Canon City, in recent years active work has shifted to Wyoming, and such as has been done in Colorado has been quite desultory and comparatively unproductive. Yet the abundance of fragments of the bones of these extinct animals in various parts of the state indicates that opportunities for such discoveries are as great now as ever. It is exceedingly unfortunate that most of the important specimens found within the borders of our state have been taken elsewhere, so that our own citizens must travel a long distance to see them. Wyoming is doing better in this line. Our own men who are interested in the subject are so burdened with their own work and so handicapped by lack of funds that it seems hopeless to look for any activity in that line. If men of means could be sufficiently interested to furnish the financial backing necessary, no doubt young men could be found who would gladly undertake the work of searching for, excavating and preparing the skeletons.

The Florissant Fossil Insects.

From gigantic reptiles to tiny insects is a long jump, but doubtless the Colorado paleontological discovery which ranks next to dinosaurs in spectacular results is the Florissant formation, with its insect and plant remains. Specimens from this formation are found in both private and public collections throughout the country, and in many European cabinets. Fortunately active work upon these smaller fossils has not ceased; or rather, having once ceased, has been revived and prosecuted vigorously very recently. The Tertiary lake bed of Florissant is situated on the Denver and Rio Grande railway, west of Colorado Springs. Fossils were first discovered there by Dr. Peale of the Hayden Survey, I believe, in the early seventies. Lesquereux worked for some time upon the plants, and Scudder upon the insects, both describing many insects as new, and identifying others as species already known from other American regions and from Europe. Quite a number of monographs and many smaller papers were published chiefly as a result of their labors, more than fifty papers having appeared prior to 1885. The early death of Lesquereux, and later the physical incapacity of Scudder prevented further work, until, in 1905, the University of Colorado reopened some of the old workings and made some new excavations, since which time a number of men from various institutions have kept more or less excavation going on each season, and have published over seventy papers, chiefly by Professor T. D. A. Cockerell, the result being that at the present time considerably more than 1,000 species of fossil insects, and 200 species of fossil plants, besides some fishes and birds, are described from that one formation of only a few square miles in extent; and barrels of material in the State University Museum and other places remain to be examined. To be useful to others, the scattered papers should be monographed.

One of the first results of this renewed activity is that, by a comparison of the fauna and flora with those of other regions, Professor Cockerell reached the conclusion that they are Miocene, instead of Oligocene, as believed by the earlier writers. It is unsafe as yet to predict the biological consequences of an extended and critical examination of such a mass of material, including so many species, from a single formation in a small area, but that the possibilities are great no one can doubt.

It is obvious that the first necessity in such a case is to assemble the material and get it identified, classified and described. This work has progressed rapidly, a number of able naturalists having been attracted to that field of endeavor, among whom may be mentioned, in addition to Professor Cockerell of the University of Colorado, the following persons: Professor H. F. Wickham of the University of Iowa; S. A. Rohwer of the United States National Museum; Professor Charles T. Brues of Harvard· Dr. Walter C. G. Kirchner; Mrs. Elizabeth G. Britton and Dr. Arthur Hollick; besides some who have not yet published any of the results of their labors in this field.

In response to an inquiry a few days ago, Professor Cockerell furnished me the following summary of some of the results which occurred to him on the spur of the moment, aside from the mere identification, classification and description of species:

1. The very large number of species preserved enables us to form a good idea of the insect and plant life of the period. There are few places where fossil species are found in sufficient numbers for this.

2. It is indicated that among insects and plants there has been very little progressive evolution since the Miocene. Some highly specialized forms which one would suppose wholly modern occur fossil at Florissant.

3. In some families of insects all the genera seem to be extinct, in others all seem modern. This need not be taken to indicate that families of the former class have necessarily undergone more rapid evolution, but rather that the extinct genera represent an ancient fauna of America, displaced more recently, perhaps, by invaders from the Old World. In the other cases, where the genera are modern, such displacement did not take place.

4. It is thus possible to form some idea of the date of the Miocene invasion via the Bering Straits region. The absence of neotropical types at Florissant, with the presence of some types which seem to have come from the Old World, suggest that the northern invasion was in progress, but the southern one via Central America had not begun.

5. The finding of tsetse flies and other supposedly Old World types at Florissant shows that it is not safe to speculate much as to the former distribution of land and water surfaces from a study of living forms alone. The evidence of paleontology must be taken into account.

6. Such fossils as the leaves cut by the leaf-cutter bees illustrate the antiquity of habits as well as structures.

TERTIARY MAMMAL BEDS.

Another exceedingly interesting and important field of research has been the Tertiary beds of northeastern Colorado, particularly in the vicinity of Pawnee Buttes, northeast of Greeley. Here was found a few years ago by an expedition from the American Museum of Natural History, one of the most perfect skeletons of the three-toed horse, besides many other species of extinct mammals not now represented by any American descendants, such as the rhinoceras, camel, etc., and very large land tortoises. An interesting problem afforded by these beds is, not the presence of certain extinct species, but the absence of many forms which should be expected. For example, the mammals which once lived in that region must have been provided with an abundance of vegetation for food. Yet a search made a few years ago, along the bluffs for seventy five miles, by an expedition from the State University, failed to bring to light any fossil leaves or plant stems. Then, too, the beds were quite evidently deposited by fresh-water streams, and possibly to some extent in fresh-water ponds and small lakes, which must have been inhabited by numerous species of mollusks, the shells of which should have been preserved in either the marls or the sandstones, yet none have been found there, so far as I have learned. This absence of fossil mollusks, together with the predominance of mammalian remains, perhaps confirms the conclusion reached from a study of the rocks themselves, that the earlier geologists were mistaken in ascribing those formations to a great fresh-water lake or inland sea.

Ordovician Fishes.

Although of little interest to the general public, perhaps the most important single paleontological discovery in Colorado is the remains of fishes in the Ordovician rocks of Canon City. The Devonian Age has been quite generally referred to as the age of fishes because in rocks of that age for the first time fishes appear not only in great numbers, but also in great variety and of great size. They were quite unlike the higher types of fishes living today, such as the trout, perch, etc., but were nevertheless fishes. Although prior to the Canon City find very few fragments of pre-Devonian fishes were known, yet biologists had no doubt that the enormous and seemingly sudden development of the fish fauna in Devonian time must have been preceded by a long period of prior development. It is the earlier stages in the development of any group of animals that are most difficult to ascertain, because the material is usually either entirely wanting, or less abundant, or fragmentary and poorly preserved. Hence any pre-Devonian fish remains are important in unravelling the history of fishes. The Canon City fishes were found associated with a large invertebrate fauna which indicated definitely that they were in an Ordovician horizon. They were described by Dr. Walcott as three distinct species, one being considered the notochord of a chimearoid, the other two ganoids. The supposed notochords are not at all common in these rocks, but certain strata contain innumerable fragments of the bony scales or plates of the ganoids. Such fossils have been found in Ordovician rocks in only a very few other places, one of the principal localities being the Bighorn Mountains of Wyoming. Two years ago similar ganoid fragments were found by the Colorado State Geological Survey in the Ohio City district, associated with Ordovician fossils as at Canon City. Professor Cockerell, in reporting these fossils (American Naturalist, XLVII, 246-247) unfortunately uses an interrogation point in the title, and language in the text which may be interpreted as indicating a doubt for which there is very little foundation. The statement that "in general, when there is a conflict between the evidence from vertebrate and invertebrate fossils, the vertebrates must be allowed the most weight," can hardly be admitted, and in any event would not be applicable to the case in point. There is no reason whatever for the supposition that such low vertebrates as these early fish-like animals are of greater value in stratigraphic determinations than some of the higher invertebrates of which quite complete, abundant, and perfect material may be found. Particularly would it be true that fragments which cannot be even generically, not to say specifically, identified, and whose family relationships are exceedingly doubtful, must be disregarded as against even a slight amount of invertebrate evidence based upon generic and specific determinations. Then, too, as "it is evident that the numerous and varied Devonian fishes had ancestors, so it is to be expected that types more or less like those of the Devonian will be found in the older rocks," therefore the author surely did not intend to say that "these fish remains, taken by themselves, would *certainly* be regarded as Devonian".

Halysites Catenulatus.

While considering this Ordovician fauna it may be well also to note that *Halysites catenulatus*, a coral which is found in the Ordovician at Canon City, and has a wide-spread distribution in Silurian rocks elsewhere in America and Europe, was found by the State Survey in the Ohio City district, associated with an undoubted Devonian fauna. This serves to emphasize the well-known rule that stratigraphic determinations based upon a single species, or supposed species, is in many cases doubtful. Large quantities of material of many species should be sought. In the first place, there is no reason to doubt that a few species belonging to the lower groups of animals, with capacity for adapting themselves to changing conditions, or in regions where conditions are changing but little, may continue to exist through long periods while the fauna in general is changing greatly. In the second place, such fossils are difficult to study critically, and it is quite possible that in animals of such low order there might be several species from different formations, whose hard parts as found fossil are indistinguishable, while if we had material with all the parts present and well preserved we would find them to be specifically or even generically distinct. Dr. Kindel reported a similar occurrence of this coral in the Devonian of Utah in 1908. (Bull. Amer. Paleont. No. 20, p. 23.)

ECHINOIDEA.

With the rapid accumulation of material, undescribed species are constantly coming to light, but usually they have very little biologic or stratigraphic significance so far as we can tell. Occasionally one is found to deserve more than passing notice. Perhaps one of the most notable species recently brought to our attention in Colorado is the sea urchin *Miocidaris cannoni* described by Jackson in his great work on the Echini, and thus specifically named in honor of Mr. George L. Cannon, one of the early members of this society. It was found in one of the chert nodules from the Millsap formation, of Lower Carboniferous (Mississippian) age, from the river wash of the South Platte near Denver. Prior to the finding of this specimen the Order Cidaroidea was not known from below the Permian. Thus it adds considerably to our knowledge of the history of that order. It is of especial interest, however, because it seems confirmatory of Jackson's previously published opinion that "two columns of plates in an interambulacral area is a primitive structure, and types having this structure are to be derived from an ancestor with one column of plates in an area, and not to be derived from an ancestor with many columns in an interambulacral area."

Thus far the discussion has been of matters of interest chiefly from the biological point of view. We come now to the geologic phases of the subject—the aid rendered by paleontology to stratigraphy.

Revising the Geologic Map.

Every geologist familiar with the region knows that only a very small fraction of Colorado has been mapped in accurate geologic detail, and that there is need of a great amount of stratigraphic work and map revision. Such work is in progress by both the United States Geological Survey and the State Geological Survey, but at the present rate it cannot be completed for many years. Meantime there is an altogether too general notion abroad in the state that the old Hayden map is final, accurate, and complete. That idea was voiced two or three years ago by a state official who was quoted in the papers as having said that a geological survey is a useless expense, because the state was long ago surveyed, and complete and accurate geologic maps made. Such an absurd statement could, of course, be made only by one who is quite unacquainted with the facts. When we consider the extent of the territory covered by the Hayden survey, with the fact that it was pioneer work in a new field at a time when the science was in its infancy, the results must be considered wonderful on the whole, but it was of necessity only preliminary reconnaissance work. It was entirely impossible for that survey to do the work in accurate detail, and as a matter of fact it did not do such final, detailed work in a single township in the state. The maps were very much generalized, the boundaries of formations in most areas far from correct, especially in areas remote at that time from the more populous districts. The larger mistakes in stratigraphic determinations were often the natural result of lack of evidence, which has since been found, but in a few cases there were simple blunders which seem at the present time wholly inexplicable. Even if the Hayden Survey had spent the time necessary to produce a complete detailed map and had made no mistakes except such as would be the natural outcome of the limited information then at hand, there would now be need of a revision. Geology is a live, progressive science, not a dead one. Much better methods of rapid and accurate mapping have been devised, and a vast amount of knowledge added to the general fund.

In the more recent work the boundaries of formations, as well as the topographic features such as junctions of streams, have often been found far from where they have been heretofore mapped, and consequently the old maps are misleading. Not only are such features being rapidly straightened out, but we are acquiring also a better understanding of the relations of formations to each other and their positions in the geologic column, and of the geologic history of the state.

Time does not permit an enumeration of the instances in which such corrections have been recently made, but a few very recent examples may be of interest.

THE RED-BEDS.

Perhaps one of the most striking instances is that of the "Red-Beds" along the foothills from west of Denver northward to Wyoming. Having no paleontological evidence, these beds were designated Jura-Trias because of lithological resemblance to formations elsewhere considered Jurassic and Triassic. The Hayden Atlas was dated 1881. In 1896 the Denver Basin Monograph still carried these beds as Jura-Trias, as also did Fenneman's Boulder Bulletin in 1905. Meantime a strong suspicion was abroad that the lower portion at least might be earlier than Triassic. To settle the question a party was sent into the field in 1907, starting in the Livermore quadrangle, northwest of Fort Collins, which is north of the boundary of the Hayden map. There were found abundant fossils furnishing conclusive evidence that the Fountain formation, and probably the Lyons formation, is Pennsylvanian (Upper Carboniferous). (Journ. Geol., xvi, 491-492, First Rept. Colo. Geol. Surv., 149-188). In 1910 another party was sent out to study the upper portion of the Red Beds, which had been named the Lykins formation by Fenneman. In this case also fossils were found in the Livermore quadrangle which showed the pre-Triassic age of at least the lower part of the Lykins. (Colo. Geol. Surv., Bull. 5, part 2.) It was easy to trace these three formations southward and remap the whole foothills region, thus in two short strokes changing the geologic map of a territory aggregating over three hundred square miles, and greatly changing our ideas of the geological history of the north central foothills portion of the state.

The Coal-Bearing Formations.

The coal-bearing rocks of Colorado were nearly all at first supposed to be Laramie Cretaceous (See Lake's report in Annual Rept. Colo. State School of Mines for 1889,) which overlies the Fox Hills, but one of the early Surveys (Stevenson, in Wheeler Survey, Vol. III, and Proc. N. Y. Lyc. Nat. Hist., 1873, p. 94.) reported that at Platteville, Fox Hills marine fossils were found above the coal. That statement attracted little attention until recently, but as more critical investigation has disclosed the fact that many of our Rocky Mountain coal fields are either post Laramie or pre-Laramie, the re-discovery of Stevenson's positive statement caused a feeling of uncertainty as to the age of the northeastern Colorado coal. Consequently at the request of a member of the United States Geological Survey, and under direction of the State Survey, an investigation was undertaken which has demonstrated that the marine fossils in the vicinity of Platteville and elsewhere throughout northeastern Colorado are underneath, not above, the coal, leaving no reason to doubt that the latter is Laramie. In the field it was easy to see how a geologist engaged in rapid reconnaissance work could be misled about the relations of the beds. This emphasizes the necessity of thorough investigations before reaching conclusions.

During the progress of this work, and some prior work in the same region, discoveries were made which also emphasize the need of guarding against the results of migrations of faunas, by obtaining fossils from as many horisons and as many localities as possible, over wide areas, and not merely from one horizon and one locality, in the solution of even apparently simple stratigraphic problems. Species which were well known as Fox Hills fossils were found to extend down into the Pierre formation as low as the Hygiene sandstone member. *Melania wyomingensis* and *Ostrea glabra*, very common brackish-water species of the Laramie, were found mingled with strictly marine species at almost every good exposure of upper Fox Hills sandstone. Now it has long been known that those two species occur in the Mesa Verde formation in western Colorado, which is the time equivalent of Upper Pierre and Lower Fox Hills. Upon the reinvasion of that region by the marine waters, the species continued to exist in brackish-water lagoons or estuaries in various parts of the Rocky Mountain area, so that upon the final retreat of the sea in both eastern and western Colorado, at the close of the Fox Hills epoch, they were ready to extend down into the brackish marshes which followed the sea in its retreat. The occurrence of the specimens mingled with marine forms in the Fox Hills beds of northeastern Colorado is easily accounted for. They were doubtless then living in estuaries or mouths of rivers whence the dead shells were carried out into the ocean by currents of water and embedded in the marine deposits, just as is happening with estuarine species at the present time. Hence in determining the problems of stratigraphic and historical geology, it is quite necessary to consider faunas as a whole and their relations to each other, rather than isolated examples.

The important coal beds of the Grand Hogback, Danforth Hills, Durango and Trinidad regions are now considered pre-Laramie, and the less important beds are Laramie and post-Laramie, while the unimportant coals of the Paradox Valley and lower Dolores river country are assigned to the so-called Dakota formation, the exact position of which in the geologic column is not certain, but is certainly very much older than the Mesa Verde and Laramie, as it is beneath the thick Mancos formation which underlies the Mesa Verde. Now one of the latest moves on the coal checker-board was the determination in 1911 that the thick beds of coal in North Park and the overlying beds in both North and Middle Parks, all mapped as Laramie by the Hayden Survey, are post-Laramie. This determination, based upon both fossil evidence and an angular unconformity, compels the revision of the map of more than 150 square miles. The same conclusion was long ago reached by Cannon and Cross, as to the exposures near Sulphur Springs.

While engaged upon that problem it was also discovered that large areas in North Park and Middle Park which were, on the Hayden map, designated Uinta (Tertiary) lake beds, are in fact occupied by the Pierre formation, of marine origin and Cretaceous age. Unlike the Platteville instance, it is difficult to see how the field geologist in this case could have been so completely misled, as marine Cretaceous fossils, especially *Baculites*, are easily found at numerous exposures. This discovery also affects the map of an area many square miles in extent.

Carboniferous Plants.

The rarity of Carboniferous coal and Carboniferous plants in Colorado has been frequently remarked. Therefore the Carboniferous plants found by Finlay near Colorado Springs and by Patton and Smith in the Grayback district, are an important addition to our knowledge of the later Paleozoic history of Colorado.

Lower Cretaceous.

Until 1905 no Lower Cretaceous rocks were known in Colorado. At that time Stanton made known the discovery of a marine Comanche fauna in the lower part of the formation which is mapped as Dakota sandstone in the Pueblo and Walsenburg folios. That portion of the sandstone is separated from the Dakota formation and mapped under the name Purgatoire in the Apishapa folio. The finding of a marine fauna in the medial member of the so-called Dakota in many places north of Boulder suggests a possible occurrence of lower Cretaceous there. Unfortunately this more northern fauna consists of fossils not specifically identifiable, so far as yet known, of types which might occur in either upper or lower Cretaceous; so the problem is unsolved for the northern area.

THE PARADOX REGION.

During the past summer (1914) over 1000 square miles of territory were re-mapped, in a wide strip bordering on the Utah line and extending north and south from the Paradox Valley. Through most of that region the boundaries of formations were found to be quite inaccurately delineated on the former maps, and radical changes in the names of formations, as they appear on the Hayden map, were necessary. The resulting map will definitely place the boundaries in that region of the Mancos and Dakota formations (Cretaceous), the McElmo and La Plata (Jurassic), the Dolores (Triassic), and the Hermosa (Carboniferous). Considerable evidence of an erosional and angular unconformity well up in the La Plata sandstone, together with the lack of a discovered unconformity here between the Dolores and lower La Plata, may indicate that the lower La Plata is Triassic, instead of Jurassic, though it is too early to express even an indefinite opinion on the subject. Among other items of interest, it may be mentioned that the narrow strip of Carboniferous gypsum shown on the Hayden map at the mouth of Gypsum Creek, really extends eastward for many miles and widens out into a body several miles in diameter occupying the head of the valley. Just over the divide, in the valley of Disappointment Creek, Carboniferous shales, sandstones and limestones aggregating 600 to 1000 feet in thickness occur. This series includes several highly fossiliferous horizons from which thousands of fine specimens were obtained in a few hours. This Carboniferous area does not appear on the maps heretofore published.

RECENT GEOLOGICAL LITERATURE

During the past twenty years the United States Geological Survey has completed and published, in the Geologic Atlas of the United States, sixteen quadrangle folios for Colorado, nearly one-half of which have appeared in the last ten years. The dates are as follows:

Number		*Date*
7.	Pike's Peak	1894
9.	Anthracite-Crested Butte	1894
36.	Pueblo	1897
48.	Tenmile (special)	1898
57.	Telluride	1899
58.	Elmoro	1899
60.	La Plata	1899
68.	Walsenburg	1900
71.	Spanish Peaks	1901
120.	Silverton	1905
130.	Rico	1905
131.	Needle Mts.	1905
135.	Nepesta	1906
153.	Ouray	1907
171.	Engineer Mt.	1910
186.	Apishapa	1913

In addition to mapping in detail the several areas covered, these folios have added a great deal to our knowledge of the stratigraphy, paleontology and geologic history of the state. Some of the more extensive works from the same survey, covering large areas east of the Continental Divide, such as the Denver Basin monograph (U. S. Geol. Surv., Mon. No. 27.) and Darton's papers on the Arkansas Valley and the Great Plains (U. S. Geol. Surv., Prof. Papers Nos. 32 and 52, 1905 and 1906 respectively.), have placed a large amount of stratigraphic information at the convenient disposal of students, while since 1906 a number of very important reports have made us better acquainted with the stratigraphy of western Colorado. Among these may be specially mentioned "Investigations of the Coal Fields of Colorado and Utah" (U. S. Geol. Surv., Bull. 316, part 2, pp. 264-375, 1907.), "Investigations of Coal Fields in Colorado and New Mexico" (U. S. Geol. Surv., Bull. 381, part 2, pp. 3-181, 1910.), "Coal Fields of Northwestern Colorado and Northeastern Utah" (U. S. Geol. Surv., Bull. 415, 1910.), and "Coal Fields of Grand Mesa and The West Elk Mountains, Colorado (U. S. Geol. Surv., Bull. 510, 1912.). During the same period the state survey has published reports covering sedimentary rocks and containing more or less paleontology, on the Hahn's Peak, Monarch, Grayback, Adma and Rabbit Ears districts, and the North Central Colorado foothills. The achievements in these various districts have all been embodied in the new state geologic map published by the state survey.

MONOGRAPHS NEEDED.

The scattered nature of the literature makes work in some lines in Colorado very difficult for any but specialists with access to large collections and good paleontological libraries. This is discouraging to amateurs who might otherwise do valuable work. It is very desirable that someone should bring together in monographic form the scattered information concerning especially our Cambrian and Ordovician formations and faunas (with descriptions and figures), by an examination of both the literature and existing collections, supplemented by some necesary field work. This has been so well done with the Carboniferous and Devonian formations and faunas of the state, as to enable the general student of paleontology who lacks access to large collections and libraries to satisfactorily work up most of the material from those formations without difficulty. I refer to Girty's paper on the Carboniferous Formations and Faunas of Colorado (U. S. Geol. Surv., Prof. Paper No. 16, 1903.), another paper by the same author on the Devonian Fauna of the Ouray Limestone (U. S. Geol. Surv., 20th Ann. Rept., Pt. 2, pp. 25-81, 1899.), and Kindel's paper on the latter subject (U. S. Geol. Surv., Bull. No. 391, 1909.). These reports describe and illustrate most of the important species, with copious references to the literature of this and other regions for purposes of comparison. There is need of a similar treatment of the Cretaceous faunas, the literature of which is scattered through many volumes and inconvenient for the use of any but specialists familiar with the various reports. The large collections of Cretaceous fossils in the State University Museum, together with a complete card catalogue of the material and of all published records, supplemented by the smaller collections in the state and the large collection from the various western surveys in the National Museum, would make the seemingly enormous task quite easy, if there were some means of publication. To do it as it should be done, with proper illustrations and descriptions of species, would require a large and expensive volume or set of volumes. In the absence of funds for such an extensive work, there is in contemplation at present an annotated catalogue of the species, including references to descriptions, figures and published Colorado locality records, and recording all available unpublished material, besides other notes of value. The greater part of the species may be found described in the various volumes of the Hayden, Wheeler, Powell, King, and other early surveys, and in such papers as Stanton's Bulletin on the Invertebrates of the Colorado Formation, but it requires a considerable amount of searching on the part of any student not quite familiar with the extensive literature.

In closing I may say that either the Colorado State Geological Survey or the University of Colorado Museum would be glad to render to anyone interested in the subject, such assistance as identification of fossils or the furnishing of information concerning their geological and geographical distribution and their scientific and practical significance. This is a part of the public service work of the two institutions. The only conditions imposed are that the material shall be accompanied with proper data as to locality, name of collector and the horizon whence obtained, where possible, and that when there are several specimens of a species from one locality duplicates may be retained for the cabinets of the institution making the identification, as partial compensation for the labor involved.

PROCEEDINGS OF THE COLORADO SCIENTIFIC SOCIETY
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THE EUROPEAN WAR AND THE MINING INDUSTRY.

By Richard A. Parker

President's Address, annual meeting, December 19, 1914.

In surrendering the chair of this Society to my successor, I do so with a sense of great obligation to my associates on the Executive Committee and to the members for the support given by their attendance at the meetings. No society of this kind can long exist, or, existing, can be of real service and value to the world without the hearty co-operation of its members. It is a matter for congratulation that the Society has prospered, notwithstanding the untoward events of the current year.

It would be unwise for anyone who has been out of touch for many years, except in a minor way, with professional operations, to attempt to deliver a technical address to the members of this Society. The great majority of you are engaged in professional work in which you are specialists; I do not say "experts" for that is a term which I am not inclined to apply to men of scientific attainments, but which I think belongs more properly to those men who are associated with promoters of dubious enterprises. But it seems to me that living as we are, in a year that will ever be memorable in history, I may be justified in briefly referring to recent events and conditions that have resulted, and the effect of such conditions upon Europe and upon this country, especially in the mining field.

Uppermost in the minds of all of us undoubtedly is the ruthless war now being waged abroad, with its frightful cost in men and money, the waste of cities and homes, and the sorrow and distress that are its attendants. Of all the losses occasioned by it, none other can equal in importance that of life. In no other war did the death rate approach that of this one, and for some time to come its continuance is indicated. When we think of the kind of men on the firing line, constituting the best manhood of the nations involved, we stand appalled at their loss. America may be a nation of shopkeepers, but truly the armies engaged are armies of artisans. Men of trades who have by their handiwork enriched the world, are difficult to replace, for it surely takes years to acquire the skill that they possess. Skilled artisans are in many respects our most important workmen, and their loss to the world is immeasurable. Skill acquired by a lifetime spent in manual training can not be bequeathed to a succeeding generation, but fortunately the influence of such a life remains a legacy of great value to a nation. Effects of such a war as is now raging are world-wide, and to us, whose principal interest is mining, they are disastrous and manifold. Happily this country is free from troublesome political alliances, but it is not wholly free—nor can it ever be free—from sympathetic business loss. No longer does a single nation, no matter how great, stand alone; our financial affairs are necessarily related to the world's finances, and consequently they have received a shock from which we are but slowly recovering. Our mining interests are hard hit. The improvement in general business conditions so confidently expected during the early part of the year, and so greatly needed, has thus far failed to appear. In this country there is probably no better single index of the general business condition than the shipment of iron ore from Lake Superior. This condition is at once manifest when I tell you that such shipments have fallen from forty-two odd million tons to a trifle over thirty million tons for the current year. While there was a general falling off in business during the early part of the year, it was accentuated by the war during the last half. The records of the steel trade show that November was the poorest month for business experienced in many years, the actual production of steel not equalling 25 per cent. of the productive capacity. The actual production dropped from a rate of 40% of capacity at the beginning of the month to 25% at the close. This condition has never before been paralleled; the price of steel continued to fall through November, until at the close of the month, the average was as low as three years ago, when the lowest point since 1898 was reached. In this connection it may be worth while to note that for the year 1913 Bessemer pig iron sold at an average of $17.19, as against an average for this year of $14.87.

The exports of steel averaged 140,000 tons per month for the first six months of this year; 114,000 tons was exported in July, 86,000 tons in August and 96,000 tons in September, while the exports for December promise to be about 100,000 tons. This indicates a slight but gradual improvement, although the entire industry is in a wretched condition and its recovery will be slow.

The income of the shareholders of the copper mines has been seriously impaired, the extent being indicated by the fact that of the twenty-eight producing American copper mines, today but nine are paying dividends, and not all of these at their regular rates. Even the wonderful Calumet and Hecla mine, with an unbroken record of forty-three years in the payment of dividends, has fallen by the wayside. Working on half time, and with copper at 11 cents per pound, the American mines can not operate at a genuine profit. As against a normal annual production of 1,200,000,000 pounds by the twenty-eight companies referred to, the curtailed operations have reduced the total production to about 700,000,000 pounds, an amount quite insufficient to meet the normal American demand and the needs of foreign manufacturers.

The general suspension of the manufacture of electrical appliances throughout the world, and the declaration of copper as contraband of war by England, with consequent great curtailment of production, and a panic price, have occasioned a general paralysis in the copper trade.

Fortunately this country has recovered from its first shock and is slowly regaining its confidence. This is shown by the advance in price of copper metal from 11¼ to 12⅞ cents per pound. Consumption, however, is still upon practically a 50% basis, and not until the war ends can we look for the production to reach its former proportions.

The average price of lead in New York for 1913 was $4.37 per 100 pounds with a production of 433,500 tons. By March of this year the price had fallen to $3.90 per 100 pounds, and in October to $3.50 per 100 pounds, since which time the price had advanced to $3.80. The production of lead in the United States for 1914 is about 100,000 tons greater than in 1913, a tremendous production continuing in spite of poor domestic demand. The price and demand for lead before the war was such that curtailment was even then thought necessary, and the war alone is not responsible for such adverse conditions. The reason the decline in price was no greater is undoubtedly the fact that at the beginning of the year the price was already so low that there was but little leeway for lower prices, coupled with unparalleled exportation of the metal.

At the beginning of the year 1914, spelter was quoted at $5.08 per 100 pounds at St. Louis, and showed a steady decline until July, when the average price had fallen to $4.75. Immediately following the declaration of war, the price promptly advanced to $5.97½, since which time it has gradually fallen until for the current month, the price will probably average $5.40 per 100 pounds.

The domestic production of spelter in 1893 was 78,832 short tons, and this has increased steadily from that time until in 1913 it was 300,491 tons. The production has practically doubled in each ten years. It may be interesting to note that the annual foreign production is practically twice that of this country, and when these figures are considered, at once the interesting fact is observed that the world production of spelter is more than 90 per cent. that of copper. The world's production of copper in 1913 was 993,200 metric tons, and over 900,000 tons of spelter.

If this war should continue for a year, in consequence of the closing of the furnaces in Belgium, Holland, Silesia and England, the total foreign production will be reduced about two-thirds, which suggests that at the close of the war there will be an enormous demand for our American product. Our production is 31·7% of that of the entire world, while our consumption is 31·4% ; figures that are at once instructive and of great interest.

The announcement of the war was a signal for a scramble for gold among the nations; Germany with its war fund was in an easy position, owing to the habit formed after the Franco-Prussian war of placing a sum into its war chest every year. By the middle of this year this accumulation amounted to over $120,000,000. England and France, however, had invested heavily in Turkish and other securities and for a time were "hard put" to raise a proper war fund. One of the measures promptly adopted by England was a stay of time for the payment of obligations, which permitted the conservation of gold, and during this period a war loan was effected.

The world's supply of gold is inelastic and practically stationary in its volume, though with a declining tendency, and this phenomenal drain caused the premium thereon to reach unusual proportions; this in turn induced an attempt by English capital to secure the gold output of some of our mines, and, failing in that, to secure the mines themselves. It is said that a premium of $7,000.00 was offered on the monthly output of the Golden Cycle mill at Colorado City, but was refused by the principal owner. These circumstances are suggestive that interest in our mines is bound to be stimulated and that meritorious gold properties will be much sought after and purchased.

As is well known, the principal market for silver has been the Far East, which usually requires two-thirds of the world's output, the remaining one-third being used in the arts and for coinage.

India, while prosperous, has not purchased its normal amount, due in a measure to the growing custom of buying gold instead of silver in which to invest its savings. Our American silver, which under ordinary business conditions would go to India, is being stored here, on account of the activity of some of the German cruisers, which have made the carriage of the metal unsafe; this condition will not last long and we may look for a resumption of our shipments to that country.

The exports of silver from London to India and China decreased over £5,000,000 during the year and up to the first of this month; while the price of silver has fallen from a high of 58 cents per ounce to a low of 48⅛ cents per ounce for October and November, and the figure for December promises to be well over 49½ cents. A fall of 10 cents per ounce in the course of one year is disastrous to the industry. The average high price for the first six months of the year was 59·4 cents, while the average low price since war began is 50·2 cents, showing that practically the entire fall occurred in the latter part of the year.

These figures, as well as those of the other metals previously mentioned, are discouraging for the present, but I am glad to state that I am assured the feeling abroad is that shortly after the war silver will go close to the $1.00 mark, while in this country it has been estimated by high authority that it certainly will reach 75 cents per ounce; this means that our silver mines will again be in demand, which is a ray of sunshine for the future.

From January, 1913, prices of all the commercial metals have fallen, showing a decreasing demand. That early in the year this was due to the uncertainties of business, caused by the impending changes in the tariff and other legislation affecting corporations, is not to be doubted, and while general business was hampered by this cause, hope was felt that upon the establishment of the Reserve Banking System, business would return to its normal condition, but the European cataclysm has given this hope a serious blow, and it would seem that only when the war is over can expansion of trade and general improvement in business conditions be realized.

Whichever way the war may be determined, at its close I am sure we will all see our business of mining and manufacturing expand by leaps and bounds.

God speed the happy day!

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TRIUMPHS OF PREVENTIVE MEDICINE.

By J. W. Amesse, M.D.

(Read at a meeting of the Society, April 3, 1915)

At a time when, among countless millions, the finer impulses of humanity are paralyzed, and civilization itself is on the rack, it seems peculiarly fitting that we, who have thus far been spared by the tempest of international strife, should not only endeavor to appraise dispassionately our material resources, but should also feel the tremendous responsibility of keeping aglow the fires of Arts and Sciences; of Education and Research.

Hitherto we have received in abundance; now we must give unstintedly. The world-horror which has burst upon us stimulates alike individual and governmental introspection. We note our frailties more promptly; we estimate our virtues less extravagantly. I shall leave to more competent hands the task of determining our preparedness for physical combat, while undertaking the more pleasant duty of assembling evidence to fortify our claims in a sphere where bullets never penetrate.

In this hour of turmoil and racial rancor, one finds the questions constantly returning: Wherein has Science made human life more tolerable? Is life more full, and death more remote than obtained with our forbears in the most distant past? Yet however much the cynicism of the moment may permeate our counsels, we can not afford to underestimate the progress of the humanities in the age in which we live.

Chief among the agencies which have contributed in the last few decades to the comfort and happiness of man has been the doctrine of conservation—the safe-guarding of all those assets which constitute national efficiency. Thus we find enactments of national and state governments directed toward the preservation of our forests, our mineral resources and our water supplies. But while these challenge the thoughtful interest of every citizen, it is in the conservation of life, our most precious asset, that our higher efforts are extended. The attitude of the public in medical affairs has so changed within the past few years that a new conception of the physician and his duties seems assured. "The modern physician aims to prevent diseases which are preventable, and treat curable diseases while they are curable" (Vaughan).

Disraeli, in one of his memorable addresses, expressed the opinion—a novel one indeed in his time—that "public health is the foundation on which reposes the happiness of the people and the power of the country." John Selden amplified this view of the great statesman when he wrote:

> "It is an axiom of the great that 'The state is all of us,' and from that we take the corrollary, 'The greatest good to the greatest number.' The function of the state is, therefore, the welfare of the people; not alone material, striving to regulate by the machinery of law their commerce; not alone spiritual, directing the thoughts of men to the things not of this earth; but equally important are the things pertaining to the public health and the physical well-being—teaching men to lead healthful, wholesome lives and thereby transmit to their children and their children's children the strength and virility of sturdy manhood and womanhood."

These sentiments are now invading our complex life so thoroughly that the ethical standard of a community may soon be judged by its death rate—municipal health being a purchasable commodity.

In the light of these encouraging signs of the times, let us review the achievements of Hygiene, the newest and most productive offspring of rational medicine.

Yellow Fever.

Perhaps the most interesting chapter in the history of preventive medicine is the story of the control of yellow fever. It reads more like a romance than a calm statement of biologic discovery. From the time it was imported into the Antilles with slave cargoes from West Africa, yellow fever was endemic on the Spanish Main, with Havana as the chief focus. From this point epidemics have gone out periodically to terrorize and destroy. Our Southern States sustained a loss of 100,000 lives in the nineteenth century, half a million further cases ending in recovery. The death rate in Mexico, Central and South America can only be approximated, but it must have been enormous. In Havana, 25,000 deaths were recorded; in Rio Janeiro, 37,000. The disease was conveyed to Europe, where devastating epidemics occurred in Spain, Italy, Portugal and Greece. It is not generally known, even among physicians, that yellow fever claimed 130,000 victims in Spain alone between 1800 and 1821. Not only the sickness and death attending these visitations, but the terror they inspired and the economic losses sustained, combined to make this disease among the most dreaded in history. We may rightly conclude then that, first among American medical conquests stands the solution of the yellow fever problem by the famous Army Commission, composed of Major Walter Reed, Lieut. James F. Carroll, Lieut. Jesse Lazear and Dr. Aristides Agramonte. From the time when this and every other plague was attributed to Divine wrath, or, as Sydenham says, "to a malignant constitution of the atmosphere," the views of competent observers have suffered constant change and have been the source of the most acrimonious discussion. Even such men as Benjamin Rush, who expressed belief in the miasmatic origin of yellow fever, were often presented with indubitable proof of its epidemic spread when introduced into salubrious regions, entirely free of so-called miasms, and its rapid dissemination aboard ship seemed to provide conclusive evidence of its communicability. The coincident plague of mosquitoes in time of epidemics was also noted by Rush as early as 1804, and later by a score of writers, but it was not until 1881 that Carlos Finlay of Havana advanced the idea that the mosquito was the intermediate host and the only factor in the transmission of yellow fever. Finlay was unable to prove this theory, however.

Recognizing the strong analogy between the propagation of yellow fever and the spread of filariasis, which a few months before had been shown to be carried exclusively by a certain species of mosquito, the Army Commission began their work at Havana with a thorough investigation of Finlay's hypotheses. In an exhaustive series of experiments, during which a number of volunteers, including Dr. Lazear, died, the theory was proven entirely tenable. Havana, Vera Cruz, New Orleans, all were freed of infection through its surprising postulates. Yellow fever must now be considered as "a disease produced in individuals of certain races by a two-host, microscopic, perhaps ultra-microscopic germ, endo-parasite of the female of a particular species of mosquito, the Stegomyia Calopus" (Finlay.)

The work of the Reed Commission has been followed by the practical extinction, in thirteen years, of one of the most terrible afflictions of mankind. From Welch's eloquent tribute to Reed I quote the following: "The discovery which he made is peculiarly American; his service to man has been paralleled in only one or two instances; it was an admirable, a classic piece of scientific investigation, second only to the discovery of the control of small-pox by vaccination."

The bronze tablet on his tomb overlooking the Potomac river bears this cherished line from President Eliot: "He gave to man control over that dreadful scourge, yellow fever."

MALARIA.

If a layman were asked which disease, among the thousand disorders that now afflict mankind, was responsible for the most acute distress and misery, the highest total mortality, the greatest disability and the heaviest loss of efficiency, he would undoubtedly name tuberculosis or pneumonia, or possibly some one of the chronic disorders, such as heart disease or Brights. It will surprise many, therefore, to know that the Captain of the Men of Death, since the world began, is malaria. It is difficult to realize, in this salubrious climate, the tremendous losses that have been sustained in the past through this world-old and world-wide pest.

Important chapters recently added to medical history seem to prove conclusively that the civilization of Greece was undermined far more through the devastating effects of this plague than through political corruption and social vice. Caravans and ships, bearing slaves from Africa, gradually encroached on a territory heavily infected with malaria. The same agencies brought to Greece the mosquito responsible for its spread, and foci of the disease were thus promptly disseminated throughout the empire.

To the Greek, quinin was unknown.

> "He had not heard of the lands where even then Nature was elaborating her first great specific. The philosophy of Plato, the wisdom of Socrates, the plays of Aristophanes, the laws of Pericles, nor the science of Aristotle could save the nation from the debilitating effects of the fever, and under its withering touch the civilization of this great people slowly, but surely, decayed. Its matchless marbles were thrown into the waste heap; its magnificent temples allowed to crumble; its altars were deserted; its literature became puerile; its philosophy lost its virility, and Greece sank into the semi-barbarism from which even now, more than twenty centuries later, it has not completely emerged" (Vaughan).

Undoubtedly the fate of Rome, with its Pontine marshes and its overwhelming infection, was hastened by the same insidious foe, and the progress of mankind thus retarded through the centuries, down to our own generation. In the tropics and sub-tropics especially, but frequently invading deeply into the temperate zone, it has remained the one constant menace to life and health.

Now, what has science done to conquer malaria? The first link in the chain which now binds this monster affliction was forged, of course, with the discovery of cinchona bark. In 1638 the Countess of Cinchona, wife of the Viceroy of Peru, after nine years' residence in that country, was seized with tertian malarial fever. Don Lopez de Canizaries, the Corregidor of Loxa, learning of her illness, sent a parcel of the bark of a tree called by the Indians "quina-quina," the duplication of the name indicating that it had medicinal properties. Just how these natives became familiar with the use of the bark is not known, but many purely fanciful tales were extant at the time. Dr. Don Juan de Vega administered the drug to the Countess, who quickly recovered, and on returning to Europe four years later, she brought with her a large supply of this potent medicine, which she distributed to persons suffering from fever on her estates in Spain. In 1670, Jesuit missionaries sent some of the bark to Rome, from whence it was distributed throughout Europe by Cardinal de Lugo. From this we derive the popular name, "Jesuits' bark." A controversy at once arose, quite naturally, as to its merits, but the efforts of Morton and Sydenham, together with the dramatic cure of the Dauphin, established the new treatment on a solid basis.

The next step in the control of malaria was the discovery of the causative organism, in 1880, by Laveran, a French army surgeon working in Algeria. This parasite belongs to the protozoa, unicellular animals belonging to the sporozoa, and is commonly known as the plasmodium of malaria. For twenty years, following the announcement of Laveran, this parasite was studied under various conditions in every part of the world, and its life history in man was completely elucidated. But how did the plasmodium gain access to the blood stream? The very name, malaria, indicates the tenacity with which the laity and even members of the medical profession clung to the theory that it was produced by poisonous emanation from marshy land. The gap in our knowledge was filled by the epoch-making researches of Major Donald Ross of the British Medical Corps. Following a suggestion of Sir Patrick Manson that the mosquito might be the intermediate host, Ross proceeded to India, where ague is more prevalent probably than anywhere else in the world except equatorial Africa, and after years of patient effort was able to demonstrate that the parasite of malaria is transmitted by mosquitoes of the species Anopheles. Italian observers immediately confirmed this discovery and proved that the Anopheles alone, of the many hundred varieties of this insect, can convey malarial infection.

It was this knowledge which enabled General Gorgas to free the Canal Zone from its ancestral plague and make this monument to engineering genius possible. Equipped with this information and the facts regarding the propagation of yellow fever, the French would unquestionably have been successful and our present commanding position in world politics be long deferred. Gorgas developed a system of restrictive measures in Cuba and Panama so thoroughly effective that we may now say with every confidence that, no matter how badly a region may be infected, or how difficult local conditions may make the application of prophylaxis, some plan can be adopted which will result in the abolition of malaria. For example, during 1906 nearly seven per cent. of the entire working force on the Canal entered the hospital each month suffering from malarial fever, while in 1912 there was less than one per cent. In the U. S. Army the rate of admission has been reduced, in the same period, from 365 per thousand troops to 25 per thousand. It may be of interest to briefly describe these anti-malarial measures, which have affected even the geography of the earth.

1. The larvae of the Anopheles within 100 yards of every dwelling are destroyed by draining the water containers, oiling the surface of collections too large to be drained, or planting minnows, which devour the larvae as fast as they are hatched.

2. Destroying all protection for adult mosquitoes within the above area. This is effected by cutting away the grass, shrubs and small trees.

3. Screening habitations and, especially, providing netting to enclose the beds.

4. The use of quinine, usually in 3 grain doses once or twice a day.

This conquest of the Tropics has come about so quietly that few realize its far-reaching import. Half a world, hitherto closed to the white man, is now thrown open for his innumerable enterprises. The mortality in many of its cities is now far below that of Denver, and Havana, formerly the mother of plagues, has become a notable health resort.

CONSUMPTON.

No discussion of state medicine would be complete without the consideration of pulmonary tuberculosis, the most ubiquitous and, next only to malaria, the most destructive disease of mankind. In its various manifestations this great plague was responsible in the year 1912, and in the United States alone, for 150,000 deaths. This tremendous amount of preventive mortality emphasizes the appalling problem which faces us in our efforts to secure some measure of control. In spite of the fact, however, that there are probably ten living cases for each death recorded, making a total of one and a half million consumptives in the country at this time, there is abundant evidence at hand to show that the incidence of the disease among our people is diminishing. In a report on the tuberculosis death rate recently presented by Frederick L. Hoffman, statistics gathered from all available sources are tabulated "to sustain the far-reaching conclusion that the mortality from consumption has actually, as well as relatively, diminished during the last thirty years." In the year 1900, for example, the mortality rate per 100,000 of population was 180. In 1910 it had dropped to 138. The aggregate mortality for those ten years, in the United States, was estimated at 1,324,723. "If, however, the rate of 180, prevailing in the year 1900, had been maintained during the entire decade, there would have been 1,559,159 deaths from pulmonary tuberculosis, or 234,436 more than actually occurred." These lives may justly be considered as saved through our broader grasp (1) of the natural history of the disease, and (2) of the means of prevention. From the census reports of the Federal Government we deduce the encouraging fact that while the mortality in New York, Philadelphia and Boston, between the years 1812 and 1821, was 418 per 100,000 persons, it had dropped to 180 in these cities in 1912. This saving in human life is, of course, of tremendous importance from an economic viewpoint, but, as Hoffman remarks,

> "The real gain is not measured alone in this form. The real triumph of the campaign against tuberculosis, in its final analysis, is the human factor, representing on the one hand the faith and work of those who, by intelligent co-operation and indefatigable industry, have reduced the warfare against this disease to a science, and, on the other, the immeasurable amount of happiness brought to the countless homes and hearts of those who, but for the success which has been achieved, would have had but sorrow and suffering, and would have faced the future in helpless despair."

In the marvelously directed fight against consumption, we may note the Federal inspection laws at immigration stations providing for the deportation of the infected; the regulations controlling the inspection of meats; the pure food laws; the activities of the Public Health Service. On the part of states and cities we have the improvements in housing; in factory and work-shop hygiene; the ordinances providing for the inspection of dairly cattle; the notification and registration of cases; disinfection of infected premises; industrial insurance; district nursing; free clinics and dispensaries; the segregation into model sanitaria and the education of the public in personal prophylaxis. All of these sociological efforts must attend the purely medical management if we expect to limit the ravages of consumption. That they will rather be increased in efficiency is amply attested by the growing belief everywhere that this is an entirely preventable disease, and that, as Pasteur affirmed, "it is within the power of man to banish all bacterial diesases from the earth."

BUBONIC PLAGUE.

Turning now from the white plague to the black, we find that one of the oldest and one of the most destructive epidemic diseases of man has been shackled through recent scientific research.

Bubonic plague has ravaged the human race since Biblical times, coming out of Asia Minor, its endemic home, in pandemic form during the fifth, the thirteenth and twice in the seventeenth centuries. On the last two occasions Europe was overrun, England was invaded, and the loss in life was estimated at more than twenty-five millions. In 1894 another outbreak began in China, soon spreading to India, Japan, the Philippines, and finally, through the medium of shipping and along the routes of commerce, it established foci in many parts of the western world. In Glasgow, Oporto, Liverpool, Rio Janeiro, Honolulu and San Francisco, limited areas of infection were found. It was restricted, through hygienic measures, in civilized communities to a few hundred deaths, while in Bombay Presidency, India, where mediaeval conditions still exist, there were over one million deaths each year from 1895 to 1901. Then, as in previous outbreaks, it subsided, to reappear unquestionably in the near or distant future. This proves that the plague has lost none of its virulence. It is still the dreaded Black Death until stayed and smothered by the hand of medical science. Read the following from Daniel De Foe's "Memoirs of the Plague," in London, written after the awful visitation of 1665:

> "The face of London was now indeed strangely altered—I mean the whole mass of buildings, city, liberties, suburbs, Westminster, Southwark, and altogether; for as to the particular part called the city, or within the walls, that was not yet much infected; but in the whole, the face of things, I say, was much altered; sorrow and sadness sat upon every face; and though some parts were not yet overwhelmed, yet all looked deeply concerned; and as we saw it apparently coming on, so every one looked on himself and his family as in the utmost danger. Were it possible to represent those times exactly to those who did not see them, and give the reader due ideas of the horror that everywhere presented itself, it must make just impressions upon their minds, and fill them with surprise. London might well be said to be all in tears; the mourners did not go about the streets, indeed, for nobody put on black, or made a formal dress of mourning for their nearest friends; but the voices of women and children at the windows and doors of their houses, where their dearest relations were perhaps dying, or just dead, were so frequent to be heard, as we passed the streets, that it was enough to pierce the stoutest heart in the world to hear them. Tears and lamentations were seen almost

in every house, especially in the first part of the visitation; for, toward the latter end, men's hearts were hardened, and death was so always before their eyes, that they did not so much concern themselves for the loss of their friends, expecting that themselves should be summoned the next hour."

What has given us control of this formidable scourge? First, Kitasato and Yersin, working independently, discovered in 1894 the bacillus pestis, shown, by experimentation and inoculation into animals, as well as through the constant presence in the blood and tissues of human cases, to be the biologic cause. Then it was found that plague is primarily a disease of rodents, and is spread to man only through the agency of the flea which inhabits the coat of rats. The British India Commission, after months of study in the investigation of every other possible source, came to the conclusion, in 1907, that in rat extermination alone we have the keynote of prevention. Thus San Francisco, New Orleans and San Juan, Porto Rico, have recently been cleared of the disease, through the rat-proofing of buildings, the proper disposal of garbage, and the extermination of rodents by trapping, shooting and poisoning. In other words—through intelligent sanitation.

Typhoid Fever.

As a sanitary problem of the first magnitude, typhoid has received probably the most intensive study accorded any disease in this latitude. In mortality it has, until recently, stood fourth, the total deaths in the United States from this cause being 25,000 annually, with 225,000 patients recovering. If one considers a moment the economic loss this represents, amounting to at least one hundred million dollars annually, not to mention the higher elements involved, he will appreciate more fully the transcendent value of the preventive measures now being inaugurated.

For at last this wide-spread disease, which so commonly attacks the young and vigorous, has been placed in the list of wholly preventable affections, such as small-pox and yellow fever. Here we find investigators from Germany, England

and America adding their accumulated evidence in preventive inoculation. As far back as 1896, Pfeiffer and Kolle began among volunteers the injection of dead cultures of the typhoid bacillus.

Sir Almroth Wright then introduced the procedure into India, where he inoculated 4,000 British soldiers, and, in 1900, during the Boer war, he and Leishman inoculated fully 100,000 troops. English results in India were fairly satisfactory, but in South Africa were very disappointing. The medical officers of our own army then took up the work and carried it to signal triumph. By using less heat in killing the bacilli used for vaccines, employing larger and more frequent dosage, the method has developed from the experimental stage to an assured position as a powerful, dependable specific. The vaccine now used in this country is made from a twenty-four hour culture, killed by heating to 60 degrees C. for one hour. The suspension of these dead bodies is then standardized with normal salt solution, so that one c.c. represents about one million bacteria. The injections are given ten days apart, three in number, and usually into the subcutaneous tissue of the upper arm. The first injection measures one-half c.c., the two others one c.c. each. The aim of this vaccination is to produce in the healthy body the development of those vital elements (known as antibodies), which are responsible for the neutralization of the poisons elaborated during an actual attack of typhoid fever.

The immunity thus induced continues for a period of two or three years, when further inoculation should be considered. The first opportunity to give this specific a proper trial came with the mobilization of our troops near the Mexican border in 1911. The division had a mean strength of 12,800 men. All were treated with typhoid vaccines. From March 10 to July 10 only two cases of typhoid developed, one in the person of a private who had had but two inoculations and whose infection was very mild, and the other in a teamster who had not been inoculated at all. Contrast this with the record of a similar body of men encamped under identical conditions at Jacksonville, Florida, in 1898. This division had 2,693 cases, with 248 deaths. Of 100,000 men in the Spanish-American war encamped in our Southern States, over 20,000 contracted typhoid. Among 80,000 young men, in the most susceptible period, and quartered in many parts of the world, there were but two cases of this disease in 1913, with no deaths. In the U. S. Navy, among 50,000 men, scattered through the Seven Seas, there were but six cases.

Every army, except that of England, now has compulsory inoculation, and most of the British troops are voluntarily receiving it. The subjugation of typhoid and its final extinction may be foreseen from these reports. There is no reason whatever to confine this certain and harmless preventive to the military forces. If all persons between the ages of 10 and 45 were to avail themselves of this prophylactic, enteric fever would soon be as rare in the United States as small-pox is in Germany, where compulsory vaccination has rendered the latter disease a medical curiosity.

Hook Worm Disease.

For millions of people in this country, the recognition of hook worm disease by Dr. Charles W. Stiles, in 1902, meant health or life. Though this infection was known to the Egyptians 3500 years ago, and is still known in the old world as Egyptian Chlorosis, the relation to a certain parasite, Ankylostoma Duodenale, was not demonstrated until the latter part of the nineteenth century. From that time up to 1902 this was supposed to be the only hook worm inhabiting the intestine of man, but in May of that year Stiles discovered a distinct species, to which he gave the name Necator (murderer) Americana. After a very extensive field investigation he proved beyond question that hook worm disease has been epidemic in the South, particularly in the sandy districts, for a century; that in its varied manifestations it has been mistaken for malaria, for simple or pernicious anemia, and for the systemic disturbances following the disgusting habit of dirt eating. As a matter of fact this perversion of the appetite is an effect and not a cause of the disease.

Coincident with the discovery of the parasite, its mode of entrance was determined by Loos. This is quite as extraordinary as the transmission of infection in yellow fever. Instead of being acquired through the food or water supply, as are other intestinal diseases, the hook worm larvae bores through the skin, usually under the feet, in persons working or walking in infected soil. The larvae reach the blood stream in a few hours and are carried to the right side of the heart. From here they are swept into the lungs, where the capillaries are smaller than the worm, and these break through into the air vesicles. They are then coughed up and either expectorated or swallowed. If ingested by the stomach they sustain no damage from the gastric juice, but pass on into the bowel, where conditions are best suited for their growth and multiplication. The hemorrhages sustained from the continued biting of these parasites, added to the infection of the wounds made by their powerful hooks, combine to produce the profound anemia and utter lack of initiative characterizing these poor patients.

Hook worm disease is found especially among children and others who at times go bare-footed; among agricultural laborers, coffee pickers, gardeners, mill-workers and in those living or working close to the soil. Thus we find brick makers, tunnel workers and miners heavily infected. The reports of the Hook Worm Commission show that probably ninety percent of the counties in our southern states, from Maryland to Florida and west to Texas, are infected with this parasite, justifying Stiles in his statement:

> "Malaria is admittedly one of the most important diseases from an economic standpoint. In general uncinariasis is in our southern states fully as important and in some respects even more so. It is reducing the labor capacity, hence the productiveness of the family, to as low as 30 or 40 per cent. Nor are the losses in wages and in the laboring capacity of the family, hence of the farm and finally of the county and state, the only economic considerations involved. Cases are not unknown where families have sold, moved or destroyed their homes because of the existence of this disease and because of their belief that it was due to the locality in which they lived. Taking what I believe to be a con-

servative view of the subject, I find it difficult to escape the conclusion that in hook worm disease we have a pathologic basis for the inferior mental, physical and financial condition of the poorer classes among the white population of the rural districts in the south."

This was written ten years ago. Since that time this menace has been brought under control through the active campaigns of the various state governments and the Rockefeller Hook Worm Commission, which has just been dissolved to engage in the broader field of international sanitary work. Several years ago it was found that thymol acted as a specific in ridding the patient of infection. Traveling dispensaries throughout the South, organized and financed by the above agencies, have in the past five years reached every infected district, made examinations to the number of hundreds of thousands, treated in the neighborhood of a million persons, and conducted an educational campaign which promises to free these regions from this distressing evil.

The International Sanitary Commission has now sent experts to various countries in Central and South America and to China where, with the consent of the respective governments, these same measures will be inaugurated. The Federal Government is now making investigations among the miners of this country, many of whom have been found infected, and restrictive efforts on the above lines will be forthcoming.

TYPHUS FEVER.

The European war has brought into prominence another disease which has always been a camp follower, and responsible for more disability, in many instances, than gun-shot wounds. Typhus fever carries the additional menace of being so easily communicable that physicians and nurses fall ready victims. Recent dispatches from the war zone in Austria and Poland, recount the terrors of this disease, and note the deaths of several Red Cross surgeons from America. It will come as a surprise, therefore, to many, to hear that the cause of spotted fever is no longer a mystery. In 1909, Dr. Howard T. Ricketts, of Rush Medical College, Chicago, determined to investigate the etiology of this affection at one of its chief endemic centers, the City of Mexico. At this time, there were scores of deaths reported from typhus daily in the Federal prison. Ricketts had succeeded, the year previous, in demonstrating the mode of the transmission of Rocky Mountain Fever, (through the wood tick), from domestic animals to man. He was exceptionally well equipped for his new venture and was voted a substantial sum to carry on this work, by the American Medical Association. In casting about for an explanation of the very infectious character of typhus, he noted the vermin swarming over the clothing and bodies of sick and well alike. Taking some of these parasites which had engorged themselves on fever cases, he allowed them to later bite monkeys and succeeded in transmitting the disease to them. Other monkeys were infected from these, outside of the prison and away from any possible source of contagion, by first feeding the vermin on the sick and afterwards transferring to the bodies of the well. So on through many series.

Experiments were then made to test every other avenue of infection, without success. In the very hour of his triumph, and while preparing to return home, Ricketts was seized with the disease and died, a martyr to the great cause we are here considering. In the prison yard of the city, the Mexican Government, in appreciation of his remarkable achievement, has erected a magnificent marble column. The prison itself has been permanently freed from fever through the simple expedient of fumigating the building and boiling the clothing of all prisoners on admission. In war time, when sanitary measures such as these cannot always be carried out, we still find typhus raging as it is in southeastern Europe, but wherever hygienic requirements can be met, it will be numbered with the diseases whose history is closed.

THE CONTROL OF SMALL-POX.

So much hostile criticism of vaccination laws has been expressed in this country and England, and so much of this sentiment is due either to ignorance or misconception of facts, that a free discussion of the question may not be out of place at this time.

When the opposition to this procedure is offered on religious grounds, I have no reply, but when based on the plea of personal liberty, the following decision of the Supreme Court of the United States will be of interest. This decision upheld the vaccination law of Massachusetts at every point, and with reference to the rights which certain people believe are infringed by these measures, it concludes:

> "The liberty secured by the Constitution of the United States does not impart an absolute right in each person to be, at all times and in all circumstances, absolutely free from restraint. Real liberty for all could not exist under the operation of a principle which recognizes the right to use his own, whether in respect to his person or his property, regardless of the injury that may be done to others."

The discovery of vaccination by Jenner in 1796 was preceded by a rather general knowledge throughout the rural population of England, that the so-called cow-pox successfully protected against small-pox. It is to him, however, we owe all the credit for putting a popular belief on a sound scientific basis through experimental processes which have never been excelled in their clearness and conclusiveness. As he, himself, wrote: "I placed it on a rock where I knew it would be immovable before I invited the public to inspect it."

The first person vaccinated in America was the five-year-old son of Dr. Benjamin Waterhouse, Professor of the Theory and Practice of Physic at the Medical School of Harvard. Thomas Jefferson became an enthusiastic convert, and, while President, helped materially to spread the new doctrine throughout the United States. In a personal note of appreciation to Jenner, Mr. Jefferson said: "Future nations will know by history only that the loathsome small-pox has existed and by you has been extirpated."

As Dr. Rosenau remarks: "This prophecy has not yet been filled, though eminently possible."

The horrors of epidemic small-pox, as seen in the pre-Jennerian period, have been spared us so long we have grown indifferent to its ravages and contemptuous toward the sole measure which has obstructed its progress. Macauley has given a most graphic picture of the inroads of this disease in ancient times:

> "That disease over which science has achieved a succession of glorious and beneficial victories was the most terrible of all the ministers of death. The havoc of the black plague had been far more rapid, but this had visited our shores but twice within living memory, while the small-pox was always present, filling the churchyard with corpses, tormenting with constant fears all whom it had not yet stricken, leaving on those lives it has spared the hideous traces of its power, turning the babe into a changeling at which its own mother shuddered and making the eyes and the cheeks of the betrothed maiden objects of terror to her lover."

Even in the eighteenth century, ten per cent of the total death rate in England was due to small-pox, and one person in every five was horribly scarred. In Prussia there were 25,000 deaths annually, in France 30,000, while in Russia ten million persons died of this disease during the century of plague.

We believe, then, the opinion of Prof. Councilman is entirely justified when he states:

> "It is impossible to overestimate the influence which it has exerted in furthering civilization and the physical and moral advance of the human race; without vaccination, and with the present intercommunication, small-pox would rage over the entire world."

From this resume, I feel we are justified in basing the following conclusions:

1. That in vaccination we have the safest, simplest and most potent specific prophylactic in the field of preventive medicine.

2. That, of itself, it is essentially harmless; the infections sometimes complicating the operation being due to faulty technique on the part of the physician, or unclean handling on the part of the patient.

Space forbids any but the briefest mention of the following conquests of disease:

Diphtheria: In the elaboration of an anti-toxin for diphtheria, Behring reduced the mortality from this infection, once so greatly dreaded, from 50 per cent to about 6 per cent—in other words it saves 44 children in every 100 cases.

Whooping Cough: A vaccine has recently been prepared, following the discovery by Bordet of the causative organism, which in most cases shortens the course of this dangerous epidemic disorder from three months to about three weeks.

As a preventive in children not yet stricken, it promises to be quite as potent as the vaccine against typhoid.

Infantile Paralysis: The germ of this justly feared disease has been discovered within the year by Dr. Simon Flexner of the Rockefeller Institute.

It is entirely probable that a curative treatment or a preventive will shortly be forthcoming from this group of scientists who are doing so much to banish the transmissible disorders.

Amebic Dysentery: One of the scourges of tropical climes. The vegetable kingdom has again given us a specific in emetin comparable to quinine in malaria. Its use in this disease transforms men from wasted, pain-racked invalids to robust individuals, and it promises to remove one of the few remaining hindrances to safe living in hot countries.

Tetanus, or lock-jaw, has been rendered preventable by an anti-toxin; beri beri has been proven to be, not a distinct disease entity, but a disorder of nutrition readily curable by a proper ration; scurvy has practically ceased to exist; rabies may be prevented by the Pasteur treatment; Malta fever, transmitted only through infected goat's milk, has been wiped out; infantile mortality has been reduced one-half in cities providing proper sanitary supervision of its citizens, and will be diminished 20 per cent further when politics is eliminated and the health officer chosen for his fitness rather than his influence. Infection in lying-in hospitals has almost disappeared.

SURGICAL ADVANCES.

The benefits accruing to humanity from the discoveries of Pasteur and the development of asepsis are nowhere better seen than in surgery. Where a few years ago blood poisoning, with all its dreadful consequences, was a common sequel to the slightest operation, and hospital gangrene and erysipelas were the nightmare of our life, to-day the merest tyro can invade with impunity practically every region of the body.

Antiseptic surgery is saving over ninety per cent of the wounded on European battle fields and mitigating the horrors of this indefensible conflict so materially that hundreds of thousands of useful lives will be spared for nobler purposes. In short, these agencies, combined with the advances in sociological administration, have lengthened human life in the past century from 23 years, to about 45. These figures are taken from the actuarial tables of the leading insurance companies of England.

The average length of life in India to-day is 25 years; in Massachusetts 45; in Sweden 50. So the domination of disease will continue until good health becomes contagious and "the days of the years" of our lives reach the span Nature has ordained.

Franklin Guiterman

CONNECTION WITH THE COLORADO SCIENTIFIC SOCIETY.

He became a member of the Colorado Scientific Society, July 7th, 1884; was elected its secretary in 1891 and held this office until 1896, when he left Denver, to become a resident of Durango, Colorado, at which time his active interest in the Society temporarily ceased. In 1907, his home again being in Denver, he resumed a lively interest in the affairs of the Society and was elected its president in 1908, which office he held for two consecutive terms.

During his secretaryship many valuable papers were presented and the Society made great progress and growth, and the same good results were shown during his presidency. The records show a number of very valuable papers prepared and read by him, among which we mention "The Determination of Iron and Copper in Ores and Furnace Products", "Gold Deposits in the Quartzite Formation of Battle Mountain, Colorado" and "On the Use, Non-Use and Waste of the Mineral Resources of Colorado", besides contributing written discussions on several other papers. His administration as president was marked by the presentation of able and valuable addresses on a number of scientific subjects, and as presiding officer he was a premier in bringing out discussions and obtaining thoughtful expressions from different viewpoints and in emphasizing the practical conclusions to be drawn.

The Society is deeply indebted to him for obtaining its present home, for a number of cases for shelving its books and for a valuable stereopticon outfit, and above all for the inspiration of his scientific knowledge and learning, his untiring energy and his ever thoughtful consideration of the best interests of the Society.

The Society never had a more loyal member.

CHRONOLOGICAL HISTORY.

He was born in Cincinnati, Ohio, March 7th, 1856. His parents, William Guiterman and Rosalie Bettman Guiterman, were natives of Bavaria, Germany, and at the time of his birth his father was engaged in the wholesale dry goods business. His early education was in the Grammar Schools and Hughes High School of Cincinnati. From there he went to the Royal School of Mines at Freiberg, Saxony, Germany, and finished his course in 1877, at the early age of 21 years. Shortly after his return to this country he came to Colorado and was assayer for the Terrible mine at Georgetown. From there he went to Leadville in 1878 and was assayer for the Little Chief mine. Leadville was his home for the next four years, during which time he held several positions as assayer and chemist for mining companies operating in that district. For about a year after this he was located at Hartville, Wyoming, supervising copper mining operations. The following year he had charge of sampling works at Silverton, Colorado. In 1885 he was superintendent of the Mingo plant of the Pennsylvania Lead Company, at Sandy, Utah. From 1886 to 1893 he was connected with the W. J. Chamberlain Company, managing sampling works and buying and selling ores. In 1894 he was manager of the Smelters Clearing House in Denver; 1895 to 1899, manager of the Durango plant of the Omaha and Grant Smelting Company, at Durango; 1900 to 1901, manager of the Pueblo plant of the American Smelting and Refining Company, at Pueblo. In 1902 he was made general manager of the Colorado department of the American Smelting and Refining Company, and in 1903 president of the Carbon Coal and Coke Company. He was called to New York March 1st, 1912, to assume additional duties and responsibilities, being made president of the New River Collieries Company and the Chesapeake and Ohio Coal Company of West Virginia. It was while making personal investigation of the underground workings of some of their properties that he contracted a cold which developed into pneumonia, resulting in his death in New York City, May 9th, 1915. It will be observed from the above chronological history that one of Mr. Guiterman's characteristic habits was developed in early life, that of application and industry, as shown by his completing the prescribed course at Freiberg at the age of 21 years. This habit followed him through life.

For about 10 years, from 1877 to 1886, he held many positions none of which was long lived, and it might be inferred by those not knowing him that these frequent changes were due to inefficiency of service. But to those well acquainted with him such inference was impossible, for it was well known that he was quick to resent interference of superiors who had no knowledge of the technical work he had in hand. During this period there were short intervals when he had no position, and this time was covered in a most practical and valuable way in research work in the laboratory of E. E. Burlingame, who allowed him its free use in recognition of his worth and merit.

From 1886 to 1893 he was with W. J. Chamberlain and Company where he acquired a most valuable experience in the handling and mixing of ores preliminary to smelting. His strict integrity and fairness in his dealings, put him in favor with both miners and smelters, and in the following year when the smelters organized a Clearing House Association, recognizing his good judgment and ability, he was made manager of the Association by unanimous choice. In this occupation he put into use a scientific basis of classification of ores, which has since been adopted generally by the smelting industry in quoting prices and in mixing for economical metallurgical work.

Now comes the turning point in his career, when, in 1895, he was put in complete control of the Durango plant of the Omaha and Grant Smelting Company, at Durango. The responsibility of success or failure was upon him. He succeeded and demonstrated that when given entire charge, the possibility of failure was eliminated. He held this position up to the time of the organization of the American Smelting and Refining Company. He was then made manager of the Pueblo plant, which had been operating with indifferent success. His management brought system, order and efficiency to the front and it was soon known as one of the model plants of the corporation. While in charge of this plant, he realized that the margin on ores contracted for might be dissipated by an unexpected increase in the price of coke at the option of the producer; and he began to advocate the acquisition of coal lands, with a view of manufacturing coke for the company's consumption. This resulted in the organization of the Carbon Coal and Coke Company and the development at Cokedale of a model coal mining and coke manufacturing industry. These marked successes led to further promotion and he was made general manager of all the plants in Colorado, including the United States Zinc Company. He was also made a director of the American Smelting and Refining Company and the American Smelters Securities Company; and in March, 1912, was called to New York in order that his executive ability might aid the other members of the executive committee to the mutual benefit of all concerned.

His career is well worthy of record in the archives of the Colorado Scientific Society. Up to the age of 40 years he had accomplished no evident great success, but by those sterling qualities of industry, energy, close application, strict integrity, fair dealing and a high sense of professional honor combined with habits of frugality, sobriety and economy, the solid foundation was made for the rapid rise and achievements that followed.

He was a devoted and loving husband and father; and his wife and son, in their great loss, merit and receive the most heartfelt sympathy of each and every member of this Society.

The loyal friend, the distinguished scholar and scientist is no longer with us but the inspiration of his career will continue a live memory, to stimulate scientific investigation and research and promote the growth and progress of the Society.

The community has lost an upright, enterprising and public spirited citizen whose place will not easily be filled.

W. A. Johnston.
L. G. Eakins.
Thomas L. Wilkinson.

Denver, Colo.,
August 1, 1915.

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GENESIS OF THE CENTRIFUGAL PUMP.

By Albert E. Guy.

(Read at the meeting of the Society, April 3, 1915)

In searching for the origins of an invention, neither the mere determination of the chronological order in which the different phases took place, nor the question as to who was prior in the art, offer as much interest or have the same value as the study, wherever possible, of the mental process which led to the gradual development of the original idea into what constitutes the invention proper. In the present instance the records are so clear that the process can be followed easily, and so interesting that the task consists mainly in translating them concisely.

Definition.

As now constructed, the Centrifugal Pump is an apparatus composed of an impeller made to rotate in a suitable casing. This casing has an inlet duct through which atmospheric or another kind of pressure forces a fluid to pass and to enter the inlet of the impeller, and an outlet duct through which the fluid under the pressure imparted to it by the action of the impeller, issues from the casing.

The fluid enters at a low velocity, and, by contact with the vanes, or blades, of the impeller, is rotated with a gradually increasing velocity until it leaves the impeller, at which time it possesses potential energy, due to centrifugal action, and kinetic energy, due to the acquired high velocity of rotation. This kinetic energy is gradually transformed into potential in the passage through the casing, so that, when the fluid issues through the outlet duct, at a low velocity, it possesses potential energy equal to the sum of the two kinds cited above, minus the energy absorbed by frictional resistance.

This description, given here so as to facilitate comparison between the early attempts and the present achievements, applies directly to what is known as the single stage pump, either of the single or of the double suction type. But to generate high heads recourse is had to a combination of stages, either in the form of single stage pumps connected to one another in series by piping, or more generally in the form of a casing divided into suitable numbers of cells, each of which contains an impeller of the single suction type and mounted on a common shaft. Each impeller does its share of the total work and since, customarily, all the impellers of one pump are made on the same pattern and are of the same size, the shares of work done are equal.

The single stage pump differs from the other in that its impeller discharges into a volute casing, whereas each multistage impeller discharges into a surrounding annular chamber, from which the fluid is led by suitable channels into the inlet of the adjacent impeller. Otherwise, the two types operate in the same manner, and, theoretically, there is no difference between them.

LEONARDO DA VINCI (1452-1519).

Unlike most other devices for raising water, the Centrifugal Pump appears to have been completely unknown to the ancients. Curiously enough, many authors have affected to recognize it as the reverse of the water turbine, claiming that with the latter device the kinetic energy of the water is transmitted to the runner as utilizable work, whereas the pump impeller spends work to impart energy, either kinetic or potential, or both, to the water. The turbine in its earliest form, the paddle wheel, was known at least 1450 years B. C., as records show, and, most likely, many centuries before that date, but that the reversed water wheel was ever used in olden times as a pump is nowhere evident.

The pump was invented at different periods widely separated; each time it appeared in a new form, and each inventor treated his device not as an improvement over others, but as one entirely novel.

In the fourteen volumes of manuscripts of Leonardo da Vinci in the possession of the library of the Institute at Paris, and which form but a small part of that prodigious work, the "Codice Atlantico," are sketches and descriptions concerning Hydraulics, which embody many of the master's observations and deductions therefrom. As a hydraulician, Leonardo was much interested in the flow of streams, the motions of vortices, "these absorbers of energy and destroyers of river banks," as he termed them. Everywhere in his sketches vortices are studied in their multitudinous forms. He discovered that they are composed of concentric layers, each having its special velocity, which thus increased from the outer circumference to the center. Unfortunately, he could but observe the facts, without being able to assign the effects to their true causes, since the science of Dynamics was not yet founded.

THE CONCEPT.

As regards the object of our study, Leonardo appears impressed most with *the fact* that in a vortex the pressure is the same at the bottom of the cavity, or bottom of the vortex, as at the upper level, which is, as we would say today, the atmospheric pressure. But in his time the existence of the pressure of the air had not been demonstrated, and it was about one century and a half later, or in 1643, that Torricelli announced the great discovery that water was raised in pumps by the pressure of air.

The reasoning process pursued by Leonardo was probably as follows, judging from his records:

(a) The main importance of the said *fact* is that there is a difference of level between the surface of the stream and the bottom of a vortex generated in that stream.

(b) Now, a syphon works because there is a difference of level, hence a pressure, or head, between the surface of the liquid drawn from and that of the discharge opening at the lower end of the long branch of the syphon.

Syphons were, of course, well known then, and had always proven subjects of great interest to men of science.

(c) The draining of marshes adjoining the sea was relatively as important a problem then as it is today. The water was, of course, at the same level in the marshes as at the sea.

(d) Water would flow from the sea level to the bottom of a vortex generated in some part of the sea. Now, if the marshy place was separated from the sea by a wall, and a syphon placed over the wall so as to lead the water from the marsh to the bottom of the vortex, in course of time the marsh would be drained.

(e) Next, provide an artificial vortex, and the invention is thus finally conceived as a method.

REDUCTION TO PRACTICE.

Figs. 1, 2 and 3 are made from photographs taken at the New York Public Library of the fac-simile of Leonardo's manuscripts. He was left-handed, and, furthermore, wrote from right to left, the writing itself being inverted, so that a looking glass should be used in order to read it. It was thought convenient to have the Figs. 4 to 11, inclusive, delineating the salient points shown in the sketches.

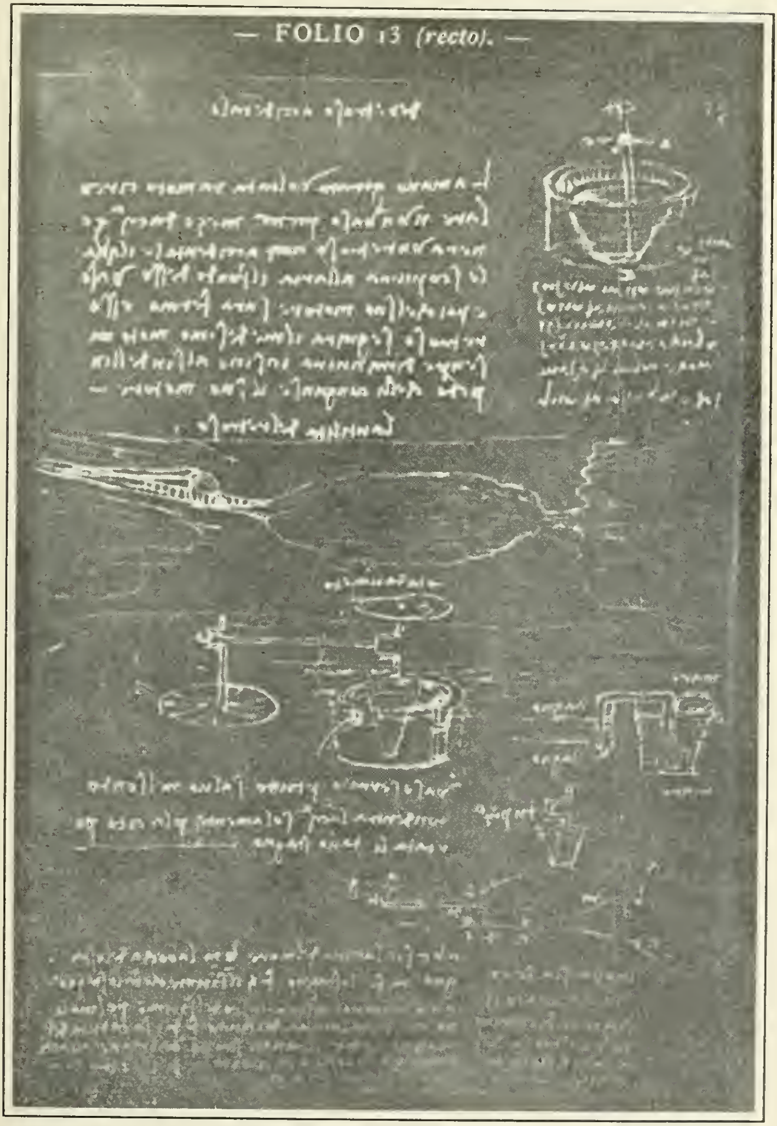


Fig. 1. Da Vinci's Manuscripts.

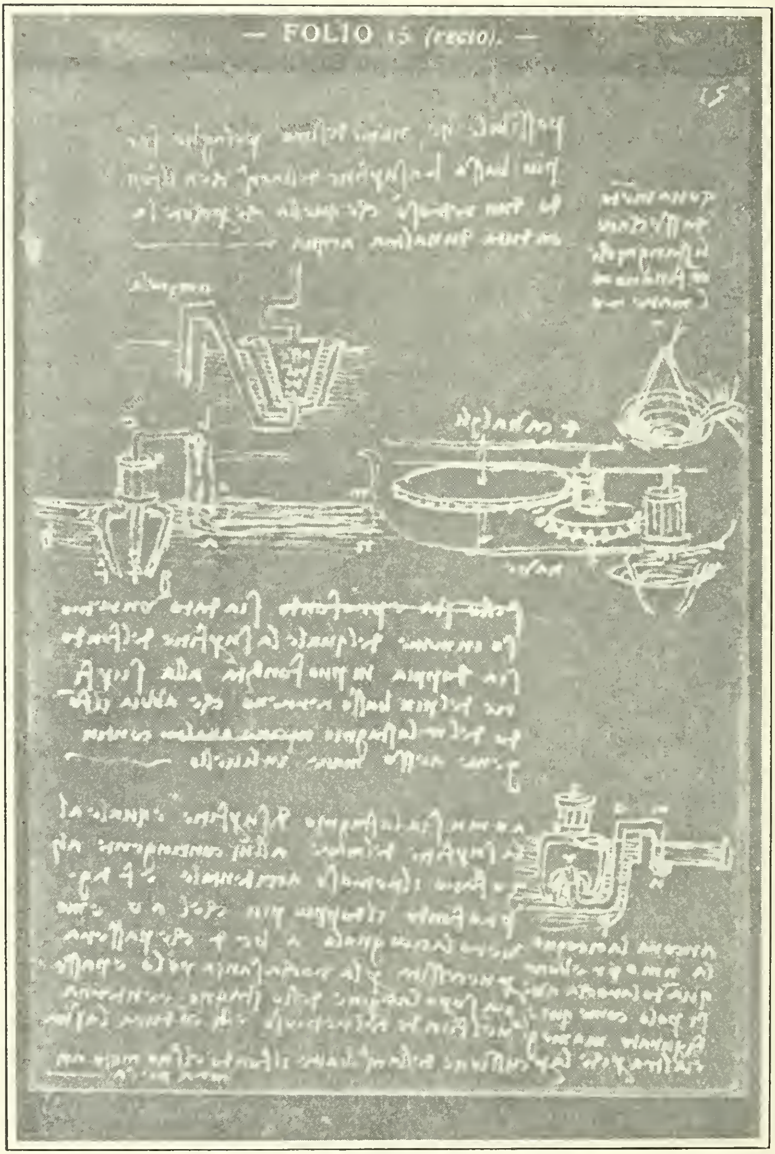


Fig. 2. Da Vinci's Manuscripts.

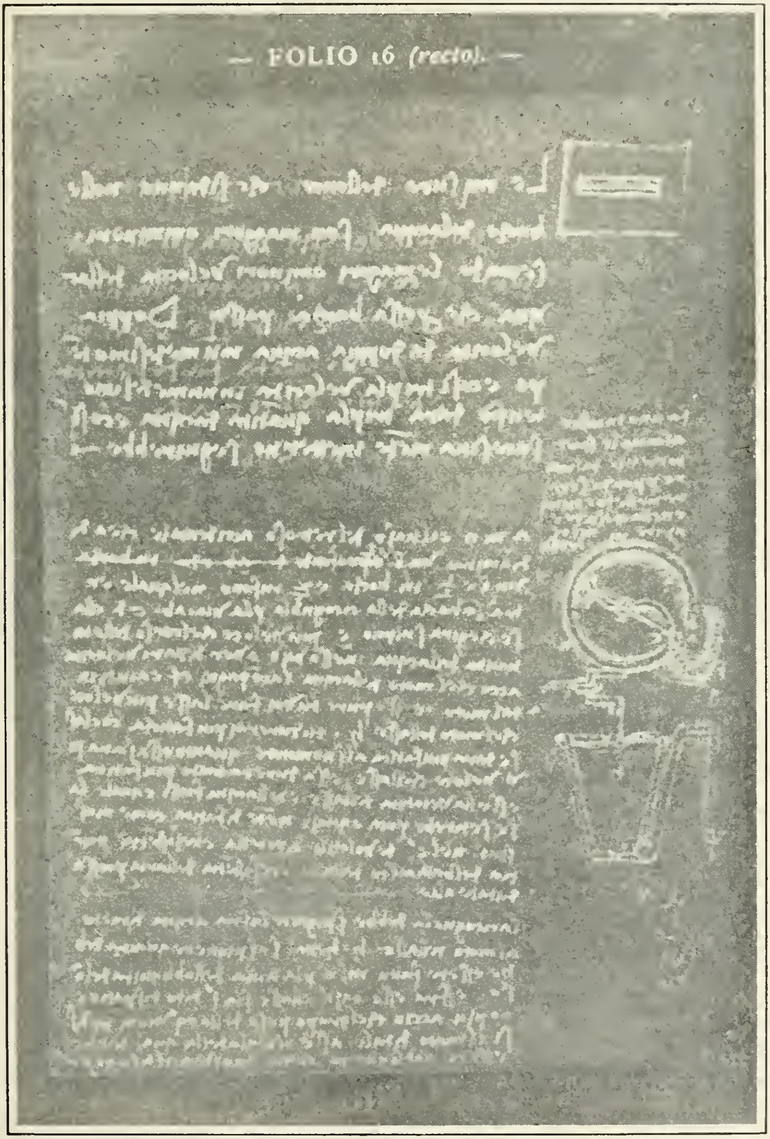

— FOLIO 16 (recto). —

Fig. 3. Da Vinci's Manuscripts.

In Fig. 4 is a vase containing water, and a rod *A-B* is rotated about its fulcrum *A*. When the movement is well established the water is entrained, a vortex is thus formed artificially, and the bottom of the vase is uncovered.

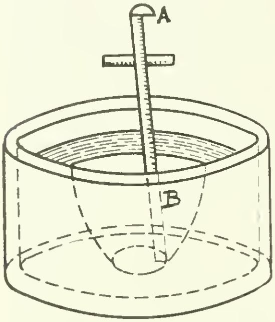


Fig. 4.

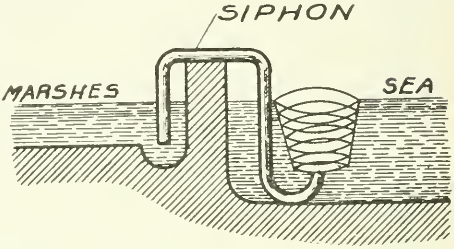


Fig. 5.

In Fig. 5 is shown the connection between the elements entering into the proposition, viz.: the marsh, the syphon, and the whirlpool in the sea.

In Fig. 6 the vortex producer is made of two symmetrical branches connected to a pulley or pinion, and the long branch of the syphon serves as a vertical axial support, about which the vortex-producing apparatus may rotate.

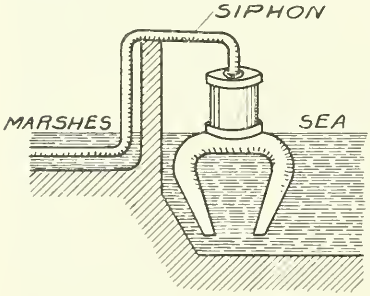


Fig. 6.

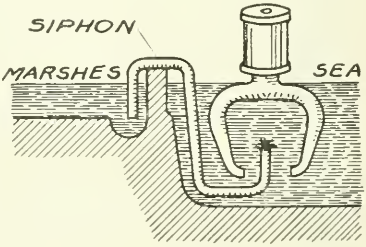


FIG. 7

In Fig. 7 the vortex producer is independent of the syphon and is to be supported in an appropriate manner.

In Fig. 8 the vortex is attached to a vertical crank-shaft having a fly wheel at the upper end; a connecting rod transmits the motion from another crank-shaft driven by a water wheel.

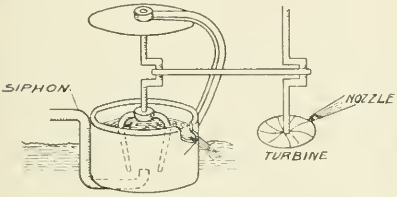


Fig. 8.

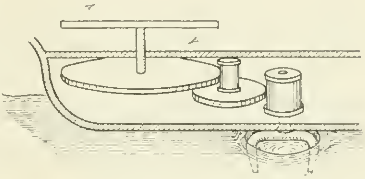


Fig. 9.

Fig. 9 represents a flat-bottomed boat, inside of which trains of gears transmit the motion to a vertical shaft, turned about by horses, to the vertical shaft of the vortex producer located underneath the boat.

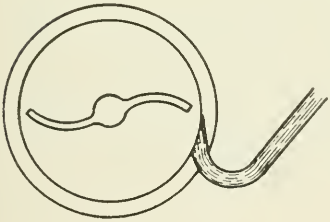


Fig. 10.

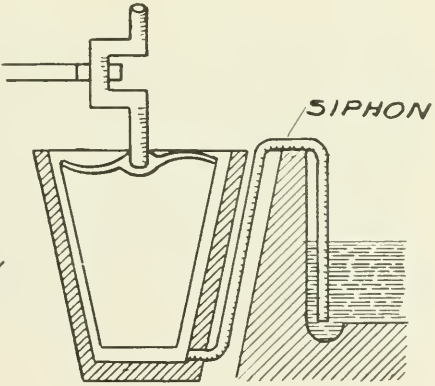


Fig. 11.

Figs. 4, 5, 6, 7, 8, 9, 10, 11 are Sketches made to show clearly Da Vinci's conceptions embodied in above manuscripts.

Figs. 10 and 11 are, respectively, the top view and elevation of an improved form of vortex producer. The primitive twin branched producer is here replaced by a double bladed impeller pivoted at the base and attached to a crank-shaft above. The form of the blade resembles much that advocated by Rittinger for fan blowers, still much used at this time. The water is discharged at the top of the recipient, or pump casing, through a suitable outlet aperture.

Apparently no records have been found to show that such a machine was actually made and tried. The logical inference is that sketches and their accompanying text were simply entered in Leonardo's notebook in the same fashion as his innumerable designs for engines of war, mechanical appliances, etc., and his plans of tunnels, hydraulic machines, and canals for traffic. But few of his practical inventions were carried out in his time, and the records laid buried in his unpublished manuscripts, and were after his death unknown and forgotten. Bonaparte brought to Paris, after his campaign of Italy, a great portion of Leonardo's manuscripts, and then Venturi called attention, in 1797, to the work of the man of genius in the domain of Hydraulics.

The Centrifugal Pump of Leonardo is operative. Practical tests of such an apparatus would certainly have suggested at once to its designer the modifications necessary to make it applicable to various services, for the man had an incomparably just and powerful grasp of natural fact and natural law.

The necessity for employing a syphon as adjunct part of the pump is not obvious, as a duct could be made to connect the bottom of the flume to that of the pump casing; moreover, the casing itself could have been installed right into the pond to be drained, the water entering through an inlet opening at the base of the casing, and the discharge led to the sea through a suitable duct. With a cover at the top the pump could have worked submerged. That such obvious operating devices are not recorded in Leonardo's notes would tend to prove that he had treated the matter simply as a problem, had found a logical solution for it, and had then passed on to other subjects of interest.

AGRICOLA (1546).

Agricola was a famous mineralogist in Saxony; he studied at Leipsic, then in Italy, and he practised for some time as a physician in Bohemia. In 1531 he was enabled to gratify his natural inclination, which was to study geology and mineralogy, by removing to the mining district of Chemnitz, in Saxony, where he had been appointed professor of chemistry. The results of his laborious investigations are chiefly to be found in his great work (De Re Matallica, Basle, 1546), which described minutely the various methods of mining, of raising and dressing the ore, and of smelting, and contains a number of curious wood cuts. Agricola is not cited here as an inventor, but in his interesting book he has described the systems of ventilation as applied to the mines which came under his observation. The photographic reproductions of some of the wood cuts contained in the book are presented here in Figs. 12A, 12B, 13, 14, 15, 16 and 17. Thus, starting with boards merely agitated over the bore of the mine, Agricola shows gradually the more complicated apparatus used for inducing fresh air into, or removing noxious gases from the mine, and finally comes to the machine approaching very much the centrifugal fan blower. The wood cuts are so explicit that it is unnecessary to give here a translation of the original Latin text. The fan blower is composed of a flat cylindrical drum, into which is rotated a number of rectangular vanes firmly fixed onto a shaft. This shaft may be rotated by man

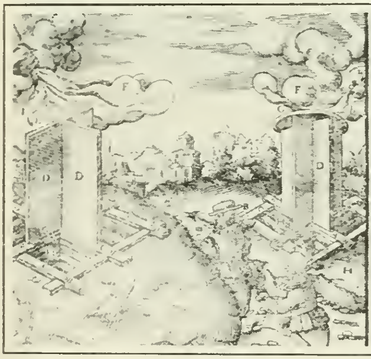


Fig. 12B.

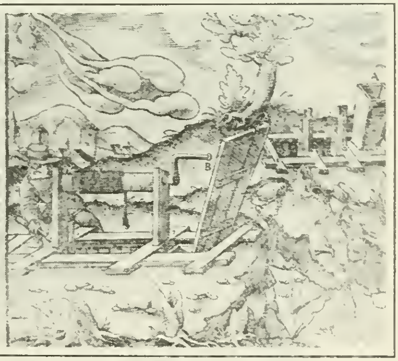


Fig. 12A.

power by means of a crank attached to one end outside of the box. For larger fans the rotation may be caused through a number of gears, the motive power being provided by a water fall. The blades are made in a great variety of ways, in some cases even feathers being used. At first glance it would seem that the description given by Agricola would cover the construction of the modern fan as we know it, but the illustrations show, and it is also expressly stated by the author, that the air comes in at a point on the circumference of the casing and is forced out of the casing at a point diametrically opposite the intake. It is obvious that the apparatus described by Agricola must have been in use for a long time before he came to know of them. It is curious to note that in 1732 a machine intended to raise water by centrifugal force was approved by the French Academy of Sciences, the description, or as we would say today, the patent bearing number 365. Now this machine is exactly the same as that shown by Agricola, for it takes in the fluid through an orifice on the circumference of a flat drum and discharges through another, diametrically opposite the intake, into a pipe leading the fluid to a trough. The intake orifice is situated at the lower point of the drum and the fluid is led to it through a vertical pipe which reaches down to the water supply. The movement of

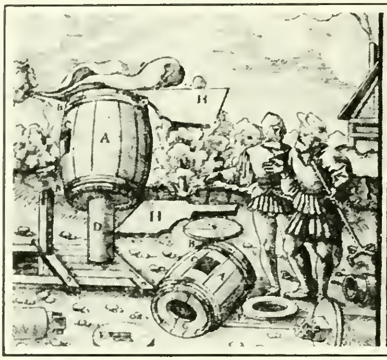


Fig. 13.

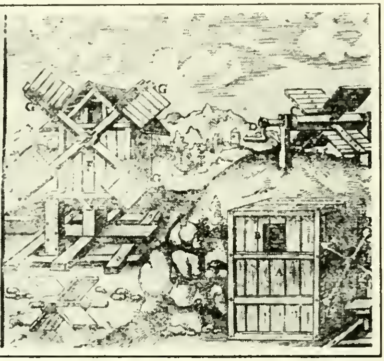


Fig. 14.

the water is caused by the rotation of six radical vanes fitting rather closely inside the drum and fixed to the shaft. A pulley is mounted on the shaft, outside the casing, and is rotated by means of a rope drive. The fact that almost 200 years after Agricola's book was published the examiners allowed the claims of the machine just described does not speak well for the knowledge of the art possessed by the "Patent Office authorities" of that period.

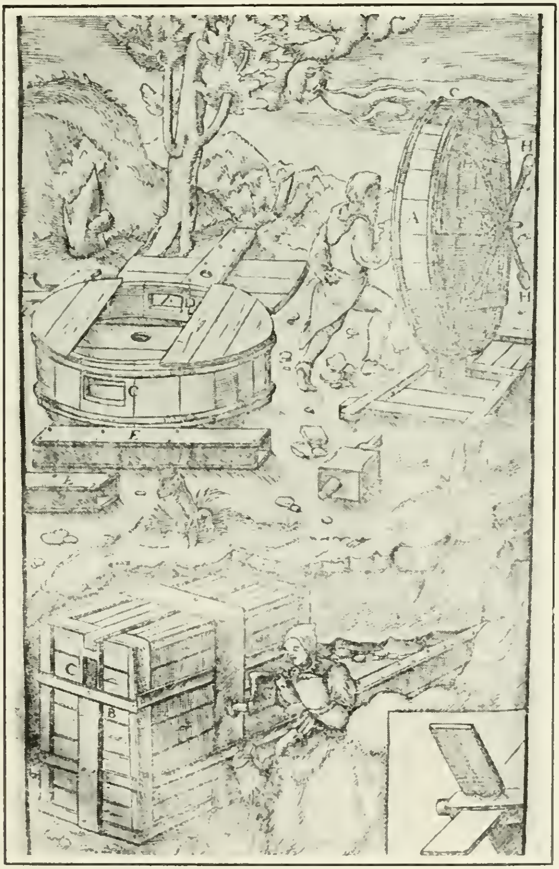


Fig. 15.

The fan blower described by Agricola was certainly operative to a degree, which is proved by the fact that the same form of apparatus was used in various industries farther back than 1830. Of course, its efficiency was very low, but it must also be said that means did not exist then for imparting to the blades themselves the high rates of rotation which are required for such machines today.

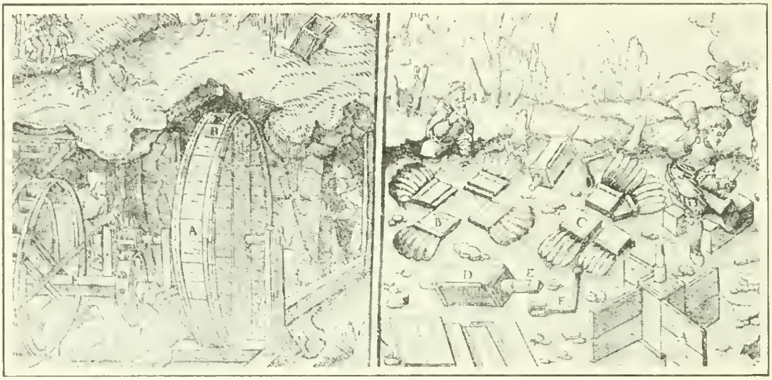


Fig. 16. Fig. 17.

Figs. 12A, 12B, 13, 14, 15, 16, 17, are reproductions of cuts from Agricola's Book: De Re Metallica.

Denis Papin (1647-1712).

Denis Papin was born at Blois, France, in 1647. He was a physicist, and is recognized as one of the inventors of the steam engine. He assisted Huyghens in his numerous experiments with the air pump and with *centrifugal apparatus*. When Newton developed his theory of universal gravitation, Huyghens, like many other scientists, could not admit the idea of action at a distance. On the contrary, he thought it possible to explain gravitation by the very rapid motions of particles placed in an ambiant medium. In order to prove his contentions, one of his demonstrations was as follows: In a recipient filled with water he placed some light bodies, such as little wooden spheres, and when the recipient was rotated about its axis, it was at once observed that the wooden spheres were driven against the axis. The explanation of this phenomenon is the same as that of the Archimedian principle; these little spheres receive a radial impulsion equal and directly opposed to the centrifugal forces that would act on the liquid whose volume they occupy.

In those times, when remarkable discoveries were dissipating the antiquated conceptions of physical laws, the philosophers had to convince themselves first, and afterwards others, of the truth of the principles advanced. And in order to do so they usually resorted to experimentation with simple objects, endeavoring thus to produce phenomena most apt to furnish, through subsequent analysis, a clear conception of the working of the assumed laws of nature.

It is obvious that experimentation of that sort was necessarily extensive, since certain series of experiments must have in many instances completely disproved, or perhaps proven exactly the reverse of, other series undertaken with just as much care.

Huyghens' experiments dealing with centrifugal effects were really very numerous, and undoubtedly their observation must have led Papin to the discovery of the principles of his pump.

Religious persecution caused Papin, who was a Huguenot, to leave France. Through the influence of Boyle he was elected a Fellow of the British Royal Society in 1680. In 1684 he received from the Royal Society an appointment as "temporary curator of experiments," with a small salary. In this capacity he carried on numerous and varied investigations, in the course of which he discovered a syphon acting in the same manner as the "Sypho Wirtembergicus" (Phil. Tr., 1685).

A certain Doctor Solomon Reisel, of Stuttgart, published in 1684 one of those challenges which the mathematicians of the age, in the spirit of the tournaments of chivalry, were accustomed to throw down to all comers, daring them to discover a geometrical mystery, known, as they fancied, to themselves alone. Papin solved the question proposed, with its six imposed conditions, and the Royal Society commanded him then to construct an apparatus which possessed all the properties enumerated in the said challenge.

His success in this instance must have led him to further investigations in the same line, and eventually he came to devise his centrifugal pump, which he really considered as a "mechanical syphon." It seems that he wanted to devise a positive syphon, simple in construction and possessing more marvelous qualities than the apparatus of Reisel. He then made a direct and beautiful application to a syphon tube of the centrifugal effects he studied with Huyghens. A complete description of Papin's invention is given in "Acta Eruditorum," Leipsic, June, 1689; but unfortunately this description is in Latin, and it is surmised that on that account it quickly passed into oblivion, since each of the subsequent inventors, as will be seen later, practically attempted to "start all over again," being apparently in complete ignorance of Papin's invention. The publication of the description under the auspices of the Royal Society, being a recognition of the invention, amounted practically to the granting of Letters Patent.

A translation of the part of the description is given in the following:

ACTA ERUDITORUM

Leipsic, June, 1689.

Description and Demonstration
before the
Princely Court of Cassel
of
Denis Papin's Lifting and Forcing Rotor.

The machine consists of one shallow cylinder *AAAA*, Figs. 18 and 19, through the center of which passes the shaft *BB*. To this shaft are fixed the blades *CCC*. extending from the axis to the inner circumference, and in such a way that with the casing fixed, the blades can freely rotate. It is obvious that the said shaft can rotate in either direction; however, it is necessary to rotate the water contained in the casing *AAAA* so as to make it recede continuously from the axis. It is true from the first principles of Philosophy observed by Descartes, and which are Laws of Nature, *that a body put into motion and left to itself will tend to travel along a straight line;* and also *that in a circular movement the body tends to recede from the axis of rotation and to leave in a tangential direction.*

The casing being tightly closed, *with the exception of one axial opening through which the water is admitted from the outside* and another at the circumference of the casing, delivering into a tube *AD* fixed in a tangential direction, it follows, then, that the water rotating in the casing *AAAA* forces itself through the tube *AD*, and thence ascends to the altitude which a body moving with the same velocity and in the same direction can attain.

If the outlet velocity is 32 feet per second, the water itself, neglecting the resistance of the air, can rise vertically to an altitude of 16 feet. With a greater or lesser velocity the altitude will be greater or lesser, but always proportional to the square of the velocity. This can be determined by the method of Galileo, given in his Dialogue on Mechanics. It is easy to calculate the velocity required to raise the water to a given height. Since the velocity can be made to increase indefinitely, no one can define the limit of action of such a wonderful machine, the proper motive power being supplied and the resistance of the air being neglected.

This invention will prove very useful, not only for supplying water to residences, where a few men will suffice to handle the apparatus, but also in connection with water displays to be started at any time and kept going any length of time. The apparatus is very simple, and all there is needed is to lead the discharge pipe as required, and at a very small expense, to a suitably elevated reservoir, from which the water is led to the spouts and various places of delivery. This machine can also be used to put out fires, as it can throw water far and as copiously as necessary.

A shallow cylinder, with a diameter of about one foot, a depth equal to one inch, and with vanes suitably disposed, will prove superior when compared to the fire engine in use at the present time. This latter apparatus consists of two cylinders, into which close fitting plungers travel, and is provided with four valves. It is easily seen that when the latter are choked with dirt, which prevents them from closing tightly, the greater part of the power exerted is then lost.

The new machine is powerful, and its cost moderate; it can be used in gardens for supplying hot or cold water; it can also be used in connection with horologes, it being adjusted so as to dip into the water, the latter by its own weight entering *the axial opening*, without suction.

In some instances it may be required to install a machine above the level of the water; this is shown in Fig. 19, where the vessel *AAAA*, tightly closed, has its inlet pipe *PP* arranged so that its lower end is immerged into the water below; the machine itself, while in motion, causes the water to ascend into the pipe *PP*, to replace that delivered through the discharge pipe *AD*.

Difficulty may be experienced in sealing the side of casing *AAAA*, through which the shaft *BB* passes; it is necessary to prevent the air from passing through the cavity in which the said shaft rotates. Were the air to enter, the water could not ascend through the pipe *PP*. It will be easy, however, to surmount the difficulty by employing leather which, formed in the shape of a ring, will press against the shaft and the casing and thus exactly fill and seal the space. In order to more completely insure the sealing, a number of such leather rings can be used, the space between them being filled with grease or other matter just as thick, which would remain there always. This place must be, more than any other in the machine, provided against the ingress of air. The other parts being securely closed and the shaft put in motion, the water will ascend through pipe *PP* and thence, pressed by the vanes, it will be forced through the pipe *AD*. This machine, performing like that of Reisel, should be called "Lifting and Forcing Rotor."

I have omitted here to show the framework onto which the apparatus is installed, and how the rotary motion is produced, but, according to circumstances, various ways may be chosen from. Thus, my first model was not provided with a base, it being a crude little machine, held in place when to be used with a cord passed around the pulley *RR* fixed firmly on the shaft. Then in this little machine the pulley caused the shaft and vanes to rotate, and it was observed that the faster the motion communicated, the greater was the force with which the water issued from the tube *DD*.

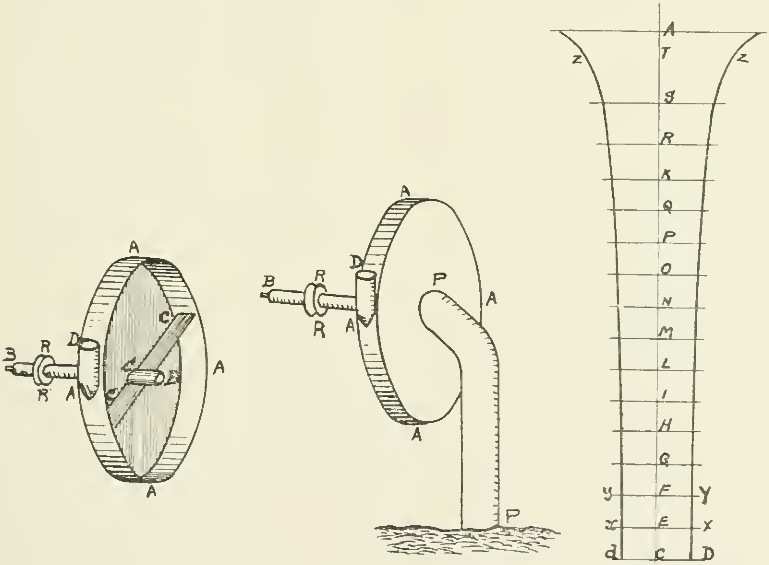


Fig. 18. Fig. 19. Fig. 20.

Fig. 18 and 19, Papin's First Pump.
Fig. 20, Papin's Idea of the Diffuser Terminating the Discharge Pipe.

Besides the uses stated above, it may be added that this machine can work very much better than bellows, when actioned by river current, weights or other force, all of which can more easily be applied to it than to the old style bellows.

It does not require such an alternating movement as is necessary to open and close the bellows; neither is it necessary to use leather, which is easily deteriorated by heat. *When it is required to displace air*, whose weight is always very small, a small power is sufficient to communicate a very rapid motion to the machine, and thereby produce a flow of very great intensity. The Prince was soon able to perceive the great variety of work that this new invention can accomplish. Since so much water can be delivered through the discharge pipe, *a corresponding quantity of air can in the same way be handled.*

If proper precautions are observed for the inlet pipe, so that the ingress of water be free from obstructions, it is obvious that the delivery pipe should be designed with the same care, and thus this machine will be found suitable for many other kinds of work besides those enumerated.

I believe nobody can point to an apparatus simpler and less liable to derangement than this one, and therefore when our kind Prince recognized my claims, his action afforded me the greatest pleasure.

I have observed that the water can be raised to a greater level by causing it to flow through the discharge pipe than it would reach were it allowed to issue as a jet. The delivery pipe should be so proportioned that as the water ascends with diminishing velocity, the cross-sectional areas should so increase that for each unit of time the same quantity of water would flow through any given cross-section (Fig. 20).

A mould can be made so that a nozzle of this form be cast in metal. It may be preferable, in case the cast nozzle should weigh too much, to construct it of sheet metal properly assembled and so formed that cross-sectional areas be proportioned as described. It must be noted that when the cross-sections figured are not placed normally to the axis, the tube becomes distorted and is not proper to suit the requirements. For that reason it is not necessary to form the tube the whole length to which the water can reach perpendicularly; a straight pipe may be used to a certain height, and thencefrom terminate in flaring out as per curve *DXY*, etc. It may also prove to be costly, both in time and labor, to make all the tubes as per the correct method, and principally so when the water is to be used at different altitudes and through different pipes; then common pipes can satisfactorily be used. However, the full benefit of the remarkable properties just exposed can only be obtained by the use of the proper discharging cone. The weight of the ascending column of water is always overcome by the momentum communicated to the water, so long as there is no lateral issue in the column.

In other machines for raising water to great heights much difficulty is experienced in making the pipes, which require to be constructed of very strong material; otherwise the weight of the water flowing continuously through would, in course of time, expand and distort them.

The shape of the delivery nozzle can be obtained by having a vertical jet of water issuing between a source of light and a perpendicular plane, so that the outline of the jet be projected on the plane, or screen, the image thus obtained would be very little out of true.

An instrument could be constructed which would delineate the desired curve *DXYZ* for small and large sizes of nozzles, the diameter and length of pipe being divided into the same number of equal parts, as, for instance, the diameter into 16 inches and the length into 18 feet.

I am preparing a number of experiments to be tried with my machine, and should anything new occur during the tests I shall duly present the facts to the judgment of the public. Meanwhile, I believe it will be seen whether, as Dr. Reisel declared, the present scheme is the same as that of the Wurtemberg syphon, or whether a difference can be found between the latter and the "Lifting and Forcing Rotor"; beyond this I keep silent. Of the two inventions, that which is capable of the greater number of applications should be publicly described.

COMMENTS.

Denis Papin reduced his invention to practice, for he constructed a working model which, when put to test, gave such good results that the inventor became very enthusiastic and, as is usual in such instances, predicted for the novel apparatus an assured supremacy over all other water or air moving machines. But he was not then able to run his pump impeller at speeds sufficiently high to permit of the detection of the inherent defects of his design and of the pump casing.

From the start he adopted, as the underlying principle of his apparatus, the law observed by Descartes, viz.: *in a circular movement a body tends (a) to recede from the axis of rotation, and (b) to leave in a tangential direction.*

In order to travel along a radial guide rotating uniformly about an axis, and to recede from this axis of rotation, *a body intended to traverse the casing and be delivered outside must necessarily enter the casing through an axial opening.* While such a statement may appear quite ludicrous and therefore unnecessary, because the matter is so self-evident, it is well to suspend judgment until the work of other earlier inventors is analyzed. Now, in view of what Agricola discloses in his book, it is clear that the older types did not have an axial intake, and since in Papin's pump the inlet was axial, that in itself was an invention.

From the axial inlet the body, in this case water, was given, by contact with radial guides or vanes, a movement of rotation. This rotation should have, and it surely did so, developed a centrifugal pressure in the casing, but that pressure was evidently neglected, because unexpected, by Papin. *His idea was that the rotation of the body caused the latter to recede from the axis and to travel radially along the guide until it reached the very end of the vane, when it would then leave in a tangential direction.* In order to guide the water as soon as it left the outer end of the vane, Papin provides, very properly, a tangential discharge pipe. This would have been very good had the water always left the vanes at the same place in the casing, but it only accommodated each vane in succession. Papin thought that all he was getting out of his pump was, as we may say today, the kinetic energy of the water issuing from the vane tip in a tangential, hence straight, direction, and with a velocity equal to the peripheral velocity of the impeller. As a matter of fact, the mass of water made to rotate in the casing was under pressure through centrifugal action proper, and the water issued through the outlet by virtue both of the centrifugal pressure and of the velocity of entrainment.

To make use of the high velocity possessed by the water issuing from the casing outlet, Papin simply invents the "diffuser." The discharge pipe, he tells us, is not complete unless it is made to terminate in some trumpet shape which can be very easily calculated and delineated.

It would perhaps seem idle to speculate as to whether Papin, with proper driving means of high speed and power at his disposition, could have realized the advantages of a discharge passage surrounding the impeller, receiving a continuous flow from the entire periphery of the latter, and so shaped as to facilitate the transformation of the kinetic energy into potential. While he might have actually so modified his original construction as to conform with the results of his observation, he would not have been able, in view of the status of science then, to explain correctly the action of his pump. However, in regards to this matter it behooves us to be very modest, since the centrifugal pump of today is very far from being correctly understood, even by its most reputed makers.

Quite worthy of remark, and entirely up to date, are Papin's advices concerning packing for the shaft and the care required to make the suction line airtight. It is not uncommon to find the user of a pumping outfit claiming failure to operate, although the pump, when tested at the maker's shop, met the specified conditions. Dilligent search by all concerned invariably brings to light the fact that air leaked through the line, either at some flange connection or through some crevice in the piping itself.

The arguments advanced by Papin against the plunger type of pump are the very ones in use today by enterprising pump agents, but as the world has grown slightly older and the centrifugal pump has obtained a good place of its own, the arguments are now very much more aggressive.

While the first description of Papin's pump is of great interest, one is nevertheless filled with regret because this most unhappy man had not the necessary means to complete his invention. But if one looks further through the Transactions of the Royal Society, and arrives at the year 1705, another description is found, given by Papin himself, of a great improvement to his pump, which he then uses for handling air in mines. The apparatus is then complete, the casing is of the volute form, and only one thing is needed to make it entirely modern—that is curved vanes instead of the radial ones he uses.

Second Description by Denis Papin (1705).

I am at present busy for a coal mine which has been left off because of the impurity of the air. I have therefore improved the Hessian Bellows, an account of which was printed at Leipzic, in Acta Eruditorum, ann 1689, with the title "ROTATILIS SUCTOR ET PRESSOR HASSIACUS," which may be applied for wind as well as water. The shape of the tympanum was cylindrical, as represented in Fig. 21, here *DAFC* is the circumference, *CP, DP, AP, FP* are the radii, which bear the wings *cm dn Ao* and *FI; CE* is the aperture through which the wind be driven in the direction of the tangent *DB;* and it may be observed that when the engine is working, every wing from the end of the aperture, till it comes to the beginning of the same aperture *C*, drives always the same air with the same swiftness and at the same distance from the center so that in going over all that circumference the air finds resistance by friction and gains nothing at all.

I therefore make the circumference of the tympanum in a special shape, as in Fig. 22, where the spiral circumference is *AFGB*, and it is to be observed that every wing in going around drives new air, because the air which is first in motion finds room to recede from the center towards the spiral circumference, and so gives room for new air to come to the wing, and when the wings come near to the aperture they drive their new air into the aperture without any friction; also the air which has been first driven and removed from the wing cannot lose its swiftness, because the wings which continually follow do continually drive new air, keeping that which is before always in the same velocity. This new shape of the Hessian Bellows affords also another advantage, because the air in going around follows the spiral line, which is nearer to the straight line than a circular circumference, and when the air comes to the aperture it gets into it without any loss of its substance; but in the cylindrical machine Fig. 21 this air always goes around in the circular circumference, and when it comes to the aperture the wind is not driven exactly in the direction of the tangent, except in the beginning at *C*,

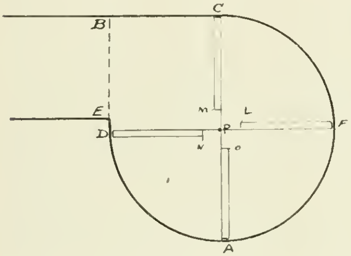


FIG. 21

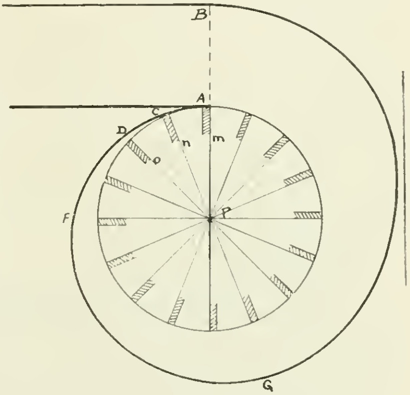


Fig. 22.

Fig. 21, Explanatory Sketch of Papin's First Pump.
Fig 22, Sketch of Papin's Second Pump having a Volute Casing.

and afterwards the impulsion is oblique, which is always increasing till the wind comes to the point *A*, and must occasion a great diminution of its strength. I believe therefore that this spiral form is a good improvement to this engine. I have made such bellows where the radius *AP* is but 10½ inches, the wing *Am* 2 inches broad and 9 inches high. Because the tympanum is also so high, or little more, the aperture *AB* was also 9 inches, or a little more, so that it makes a square hole. When I work this engine with my foot it makes such a wind as to raise up 2 pounds weight, and a stronger man could do much more, but this is more than sufficient for our purpose, since we need only drive air enough for the respiration of such men as can work in the mine; and we can easily make wooden pipes with boards to conduct the wind to the very bottom, so that the air within may be continually renewed as well as without.

I have made some trial of the Hessian Bellows in a very strong fire in a furnace to melt glass, iron or other hard metal, and though I could open the furnace above the matter to be wrought upon, yet no flame would get out through the aperture, nor could cold air from without get into the furnace, so that it is very likely this will be a great convenience for several sorts of works, since men may work the matters when they are most softened in the fire; and they may be drawn up perpendicularly, so as not to be bent as they are when drawn horizontally. I believe this would be a good way to make glass pipes and looking glasses of extraordinary size, and I think that the Hessian Bellows may be applied to several good uses and so deserve very much to be improved.

Teral (1728).

Fig. 23, reproduced from Volume 5 of the "RECUEIL des MACHINES," approved by the French Academy, represents a "continuous blower," submitted to that Academy by Mr. Teral in the year 1728. The impeller has radial vanes, the casing has the volute form advocated by Denis Papin, and the apparatus is provided with a tuyere suitable for foundry work; in fact, mention is made of this apparatus in some papers of that period in connection with mine and foundry undertakings.

The air is admitted not axially, but through a number of circular openings placed on a circle concentric with the axis. Since the vanes extend outward from the shaft, the correct

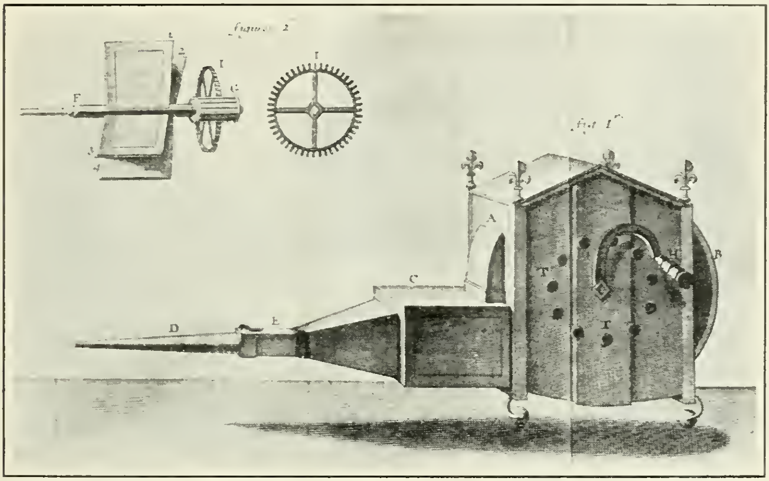


Fig. 23, Teral's "Continuous Blower."

centrifugal effect claimed by Papin for his blower does not fully obtain in the Teral machine, although the latter is quite effective. This consideration evidently led the Recorder of the Academy, immediately after the description of the machine, to state that Teral's idea was not novel, that similar blowers could be found described in Agricola's De Re Metallica, and that such machines had been in use to winnow grain. Nevertheless, Teral's machine is in appearance all that we would expect an up-to-date forge blower to be, minus, of course, the unnecessary ornaments shown in Teral's drawing.

In view of the expressed opinion of the Recorder, it seems likely that Teral did not invent a novel blower, but merely constructed one to suit certain requirements of the trade, and, having succeeded in that, he presented a drawing and a description of the apparatus to the French Academy, so as to obtain the valued seal of approbation of that body. Hence, we may draw the conclusion that such machines were in current use in those times. But since Papin used his machine for pumping water, as well as for blowing air, and published an account of his invention, it is remarkable that in 1728 the Recorder did not mention Papin's invention.

Le Demour (1732).

The French Academy approved in the year 1732 the invention of Mr. Le Demour, a Frenchman. At that time the effects of centrifugal action had become well recognized and had been studied to some extent. Le Demour brought forth a remarkable application of such action, and finally embodied it into a machine for raising water. It is not known just how the invention was conceived, but that may be surmised from the fact that of the two machines successively described to the Academy, viz.: No. 363 and No. 364, the former consisted merely of a straight tube attached in an inclined position to a vertical axis, and when whirled around by a handle attached to the axis, the lower end of the tube rotating in a basin of water, the centrifugal action would cause the water to ascend in the tube and be projected outward at the upper end. It is unlikely that the invention was thought out as a problem; it is more plausible to admit that the inventor observed the curious effects produced with a tube which he himself had occasion to rotate in a basin of water. Then he devised the apparatus shown in Fig. 24. Later he developed the machine shown in Fig. 25. It was usual in those times to represent new engines driven through trains of gearing by a water wheel, since no other source of power but that of a water fall or stream was available. Le Demour's pump seems to have been the pioneer of quite a series of apparatus. For handling a large quantity of water a multiplicity of tubes had to be used; hence, a good deal of work was lost in friction, and coupled to that the kinetic energy of the water issuing from the discharge end of the tubes was totally lost. The efficiency of the pump was consequently very low. Besides, the pressure generated by the centrifugal action being used to force the water out of the tubes to project it into the stationary receiving trough, obviously such a pump could not be used to discharge water directly against a head. Thus limited in its action, and having a poor efficiency at that—General Morin places it at 20 per cent.—this pump remains only as a curiosity, and has never really entered into practice.

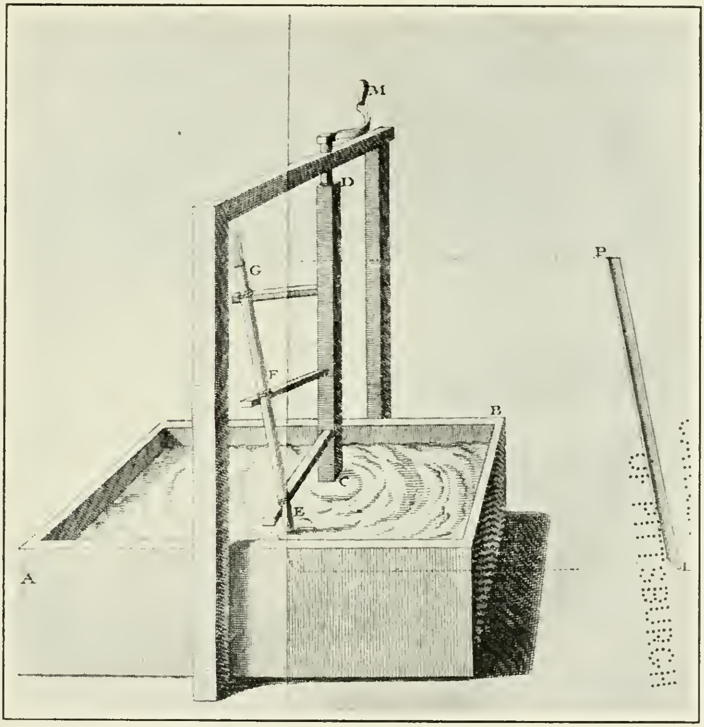


Fig. 24, Le Demour's Pump.

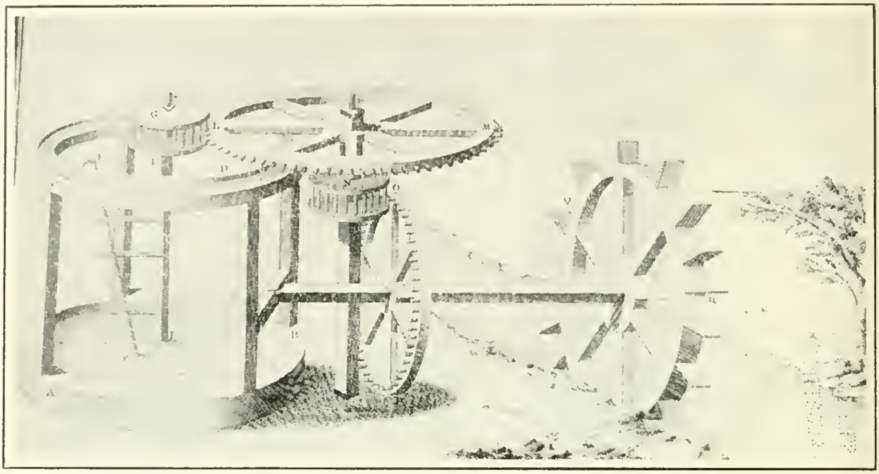


Fig. 25, Le Demour's Pump.

J. T. DESAGULIERS (1734).

"Experimental Philosophy," an extensive work on Physics and Mechanics, written by Dr. J. T. Desaguliers, had a well deserved vogue in England, and afterwards on the Continent when fully translated in the French language. The Postscript of the Second Volume contains a most interesting description of a centrifugal fan; the apparatus is similar to the first machine built by Papin, in so far as the casing is concerned, and was therefore bound to prove inefficient. But a decided innovation was introduced in the design of the impeller proper. Whereas Papin employed the open type of fan—that is, with vanes attached to the spindle, radiating from the axis and running with a small clearance within the lateral walls of the casing—Desaguliers brought forth, so far as is known today, the first original type of the enclosed impeller. One web is fixed to the shaft; radial vanes are attached to it on one side and hold on the other a web having a circular opening at center to serve as the inlet to the fan proper. The modern impeller differs from Desaguliers' only in that the vanes are curved instead of straight, and in that it is detachable from the shaft.

A second innovation, recognized of far greater importance today than in Desaguliers' time, was the means of reducing leakage from the pressure side of the casing to the intake. Desaguliers is the first on record to employ packing rings. He used thick "blanketing" fixed to the impeller and made to rub against flat surfaces on the casings. Much frictional work was thereby produced, detrimental, of course, to the efficiency of the apparatus. Today the packing rings in high grade machines are made to operate within very small clearances and without rubbing.

Desaguliers' own description of his apparatus is given in the following:

An Account of an Instrument *or* Machine *for* changing the Air of the Room of *sick People in a little time, by either drawing out the foul Air, or forcing in fresh Air, or doing both successively, without opening Doors or Windows.*

N. B. *The Model of this Machine, made by a Scale of an Inch to a Foot, was shewn the* Royal Society *the thirteen Day of* June, 1734, *by Dr.* J. T. Desaguliers, *F. R. S.*

Fig. 26 represents a Case D E C B, containing a Wheel of seven Feet in Diameter, and one Foot thick; being a cylindrical Box, divided into 12 Cavities by Partitions directed from the Circumference towards the Center, but wanting nine Inches of reaching the Center, being open towards the Center, and also towards the Circumference, and only clos'd at the Circumference by the Case, in which the Wheel turns by means of an Handle fix'd to its Axis A, which Axis turns in two Iron Forks, or half concave Cylinders of Bell-metal, such as A, fix'd to the upright Timber or Standard A E.

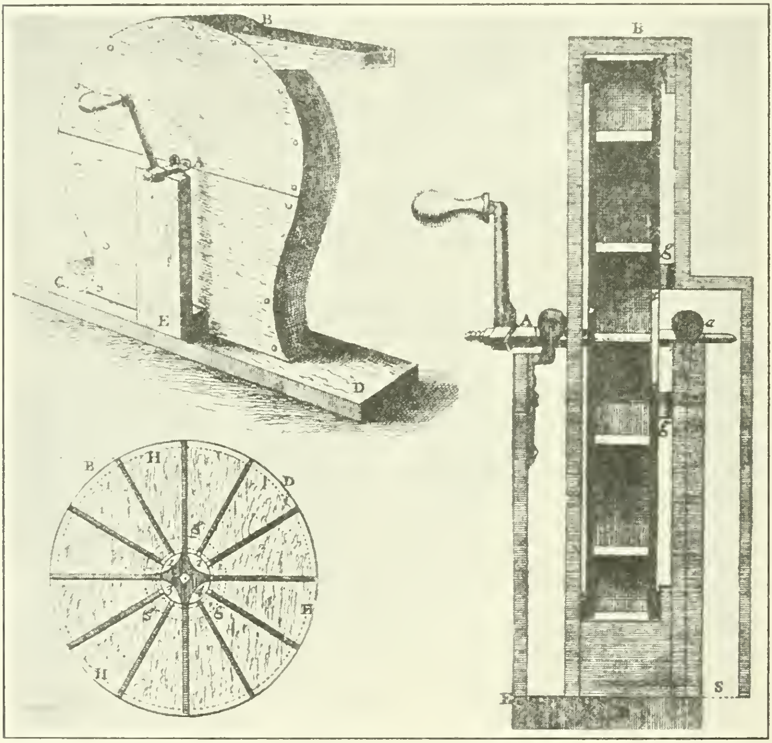
From the middle of the Case on the other side behind A, there comes out a Trunk or square Pipe, which we call the Sucking-Pipe; which is continued quite to the upper Part of the sick Person's Room, whether it be near or far from the Place where the Machine stands, in an upper or lower Story, above or below the Machine. There is a circular Hole in one of the circular Planes of the Machine of 18 Inches Diameter round the Axis, just where the Pipe is inserted into the Case, whereby the Pipe communicates with all the Cavities; and as the Wheel is turn'd swiftly round, the Air which comes from the sick Room is taken in at the Center of the Wheel, and driven to the Circumference, so as to go out with great Swiftness at the Blowing-Pipe B, fix'd to the said Circumference.

As the foul Air is drawn away from the sick rooms, the Air in the neighbouring Apartments will gradually come into the Room through the smallest passages: But there is a Contrivance to apply the Pipes which go to the sick

Room to the Blowing-Pipe B, while the Sucking-Pipe receives its Air only from the Room where the Machine stands. By this means fresh Air may be driven into the sick Room after the foul has been drawn out.

THIS Machine would be of great use in all Hospitals, and in Prisons: It would also serve very well to convey warm or cold Air into any distant Room; nay, to perfume it insensibly, upon occasion.

Fig. 27 REPRESENTS the Inside of the Flat of the Wheel which is farthest from the Handle, and next to the Sucking-Pipe.



Figs. 26, 27 and 28, Desagulier's Fan.

1, 2, 3, 4. REPRESENTS the Cavity or Hole which receives the Air round the Axis, having about it a circular Plate of Iron to hold all firm; which Plate is made fast to the Wood, and to the Iron Cross that has the Axis in it.

g g g DENOTES, by a prick'd Circle, a narrow Ring of thick Blanketting, which (by pressing against the outside Case, whilst it is fix'd to the outside of the Flat of the Wheel) makes the Passage into the Wheel tight.

H H H is another Circle of Blanketting, likewise fix'd to the outside of the Wheel, and rubbing against the Case, that the Air violently driven against the inner Circumference of the Case, may have no way out, but at the Blowing-Pipe at B.

THERE is on the outside of the other Flat of the Wheel, where the Handle is fix'd, a Ring of Blanketting, like H H H, opposite to it; but none opposite to *g g g*, because the Wood there is not open, but comes home close to the Axis.

Fig. 28 GIVES a vertical Section of the Wheel and Case a little forward of the Axis, drawn by a Scale twice as large as that of the other two Figures.

A *a*, the Axis supported by the Irons A, *a*, cylindrically hollow'd, except the upper Part, where a Pin keeps in the Axis.

B D, the Case with the Sucking-Pipe S *a*.

E A, the Prop for one End of the Axis.

1, 2, the Opening into the Wheel.

g g, the Eminence of the Wood, to which is fix'd the small Ring of Blanketting.

THE four black Marks, one of which is near H, represent the Sections of the two other Rings of Blanketting.

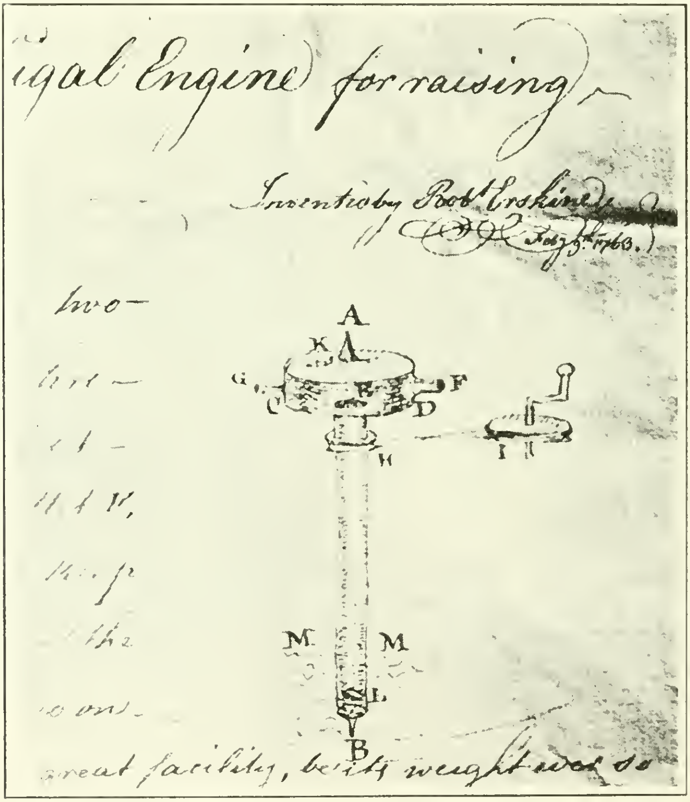
N. B. *There is no need for the Blanketting about the Circumference of the Wheel.*

IN the latter End of the Summer of the Year 1740, the Lords of the Admiralty order'd me to shew them the Model of my centrifugal Wheel and Air-Pipes; which having done, some of their Lordships did me the Honour to go to the House of Commons, to see the Operation of the Wheel fix'd there. Sir *Jacob Ackworth* attended them, and seem'd to approve the Machine as well as they did; and I was order'd to make a Blowing-Wheel with its Pipes, to be try'd on board the *Kinsale* at *Woolwich*, but less than that at the House of Commons, that it might not take up too much room in the Ship.

ROBERT ERSKINE (1763).

Figure 29, reproduced from "POWER AND THE ENGINEER," issue of January 5th, 1909, illustrates a centrifugal pump invented by Robert Erskine. Mr. Edward P. Buffet, author of the article in "POWER," made searches through the Erskine manuscripts preserved in the New Jersey Historical Society, and found the description of this pump. The article is here quoted in part.

"'Among the inventions that Erskine developed as practical machines was a 'Centrifugal Engine,' or rather pump, very simple in principle. If, as he shows, we have a pipe not too long for suction, and shaped as an inverted *L*, the lower end being immersed in water, and if after having started a stream flowing we continue to revolve the pipe with sufficient speed about its vertical axis, the centrifugal force of the water in the arm will produce a continuous flow. The top part may, if desired, be made in hollow disk form, with several orifices, but their total cross-section should be less than that of the inlet pipe. The mechanical development of this conception was easy. Obviously the device had advantages as a pump through minimizing the number of moving parts and reducing frictional loss. The Erskine papers contain several sketches of this pump, whether in its most elementary form or put into more marketable shape. Fig. 29 is a drawing that appears on a sheet bearing date February 9, 1763, the time of the writing, or of the invention.



-igal Engine for raising

Invention by Robt Erskine
Feby 9th 1763.

two—

great facility, be its weight was so

Fig. 29, Robert Erskine's Pump.

"This centrifugal pump was offered as a competitor of the chain pump for bailing out ships.

"'A correspondent of the 'GAZETTEER,' signing himself 'W. B.,' had attached the centrifugal pump in favor of the chain pump, for we find among the Erskine manuscripts drafts of a letter to the printers of that paper in rejoinder, taking to task 'W. B.' for having 'endeavored to impose on the *ignorant*.' One such document is signed with Erskine's name, and another, somewhat differently worded, with the disinterested nom de plume 'Mechanicus.' It does not appear which he employed in the letter as finally sent off.

"'He opened his defense with the remark that the invention had been suggested by a problem which one of the 'Gazetteer's' own correspondents had proposed, viz.: 'contrive a method to make the syphon run out of the shorter end by means of an air pump.' Erskine stated that one of the machines might be seen at Mr. Coles, near St.Thomas' Coffee House, on the Strand, and proceeded to describe it. With such a pump six men could raise two tons of water in a minute at least 20 feet. The delivery increased faster than in proportion to the power applied. The radius of the ejecting tubes of the present engine, designed for a 60-gun ship, was 4 feet. He went on to compare the velocities of motion of the centrifugal and chain pumps under practical conditions of operation and to demonstrate that 'W. B.' had assumed feats of sustained human activity quite unreasonable to expect. Further, he pointed out that his own machine possessed advantages in its simplicity, high mechanical efficiency and freedom from liability to injury by anything less than a cannon ball.'"

Erskine had great difficulty in proving his claims when he applied for a patent in England. The examiners cited in opposition the description of Le Demour's machine. The two pumps were evidently in the same class, but they differed in construction.

DUCREST (1777).

The Marquis Ducrest published in Paris, in 1777, his "Essays on Hydraulic Machines," in which he described exactly the same construction as that of Erskine, and claimed to have invented it. It is not probable that Ducrest was aware of Erskine's inventions.

THE PRACTICAL MECHANIC'S JOURNAL.

Historical Review to 1851.

The Centrifugal pump came fully into the light in 1851, during the Great Exhibition in London, and again in 1855, during the Paris Exposition.

Three makes of pumps were in exhibition at London, and a rivalry started between these makers, namely, Appold, Bessemer and Gwynne, each backed by numerous adherents, which did more to establish the practical status of that type of pump than anything else that could have been devised to that effect.

The "Practical Mechanic's Journal" for 1851, Vol. IV, page 121, printed an interesting historical review of the Centrifugal Pump, in order to "perhaps throw a little more light on the matter." That paper describes the invention of the Le Demour, 1732, as being the first on record. Then comes the Erskine pump, followed by its modification by Victor Jorge, in 1816, which consisted in giving motion to the arms of the pump only, so as to save the power lost in driving the upright tube and allowing of the latter being inclined to any angle, as circumstances might require, without interfering in any way with the action of the pump.

In 1818 appeared the "Massachusetts Pump," the inventor of which is unknown. This machine was based on Papin's second description, the casing being made in volute form (Fig. 30 and 31). It had in addition a quite novel feature, in that an axial inlet opening was provided in each side of the casing, thus making the pump of the double suction type. The impeller was not shrouded, and was therefore of the open type with radial vanes.

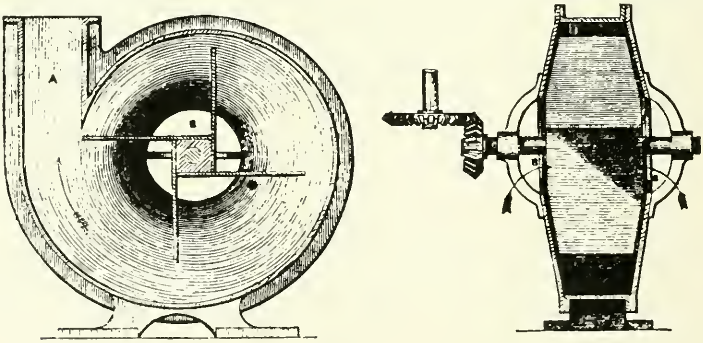


Fig. 30. Fig. 31.

Fig. 30 and 31, Massachusetts Pump.

1830.—The same principle of pump made its appearance in 1830, in New York, with several improvements, and exhibiting satisfactory performance.

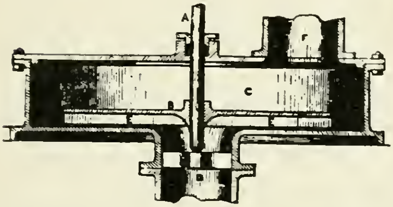


Fig. 32.

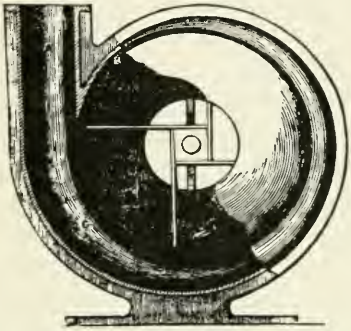


Fig. 33.

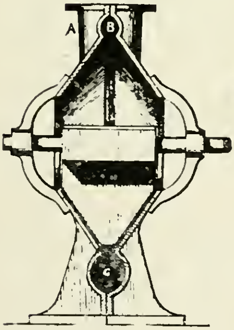


Fig. 34.

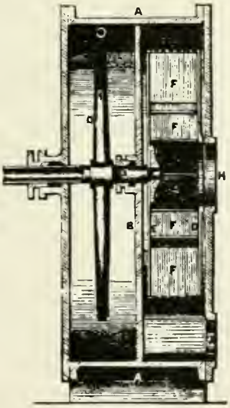


Fig. 35.

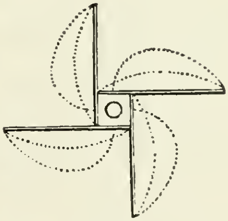


Fig. 36.

Fig. 33, Blake's Pump. Fig. 33 and 34, Andrew's Pump.
Fig. 35, Bessemer Pump. Fig. 36, Andrew's Improved Pump.

1831.—Blake (Fig. 32). Apparently the next improvement was that by Messrs. Blake of the New Steam Mills, Connecticut. Their machine was remarkable as being the earliest known example of Centrifugal disc pump. The vertical driving shaft had keyed upon it a single horizontal disc, working inside and at a short distance above the bottom of the fixed casing. The shaft is supported in a footstep carried in the suction pipe which opens out from a central hole in the bottom of the case and extends to the reservoir of water to be lifted. To the under side of the revolving disc are attached a series of radiating blades working just clear of the bottom of the case.

1839.—Andrews (Fig. 33 and 34). The continued additions to the general fund of information on the employment of Centrifugal force for pumping purposes led to the first patent for mechanism of the kind in 1839, in the United States. The invention was made by Mr. W. E. Andrews, whose pump was publicly employed in the harbor of New York in 1844-45.

In all points except the form of section of the periphery of the case this pump closely resembles the Massachusetts form. The water, as in it, is here taken in on each side at the center of the case and expelled by the centrifugal action through a tangential volute duct. Commencing with a considerable breadth at the center, the blades taper off quickly nearly to a point, terminating a little short of the circumferential line of the straight portions of the sides of the case which are concentric with the shaft. From there on the water is discharged into the volute duct, which is in effect as if a separate member of the pump.

1841.—Whitelaw. At the latter end of 1841 Mr. James Whitelaw of Johnstone published sketches of two forms of pumps, showing the relative effect of straight and curved arms, working on what may be termed the "inverted Barker's Mill Principle." He also furnished calculations as to the duty of such pumps.

1844.—Gwynne. In 1844 Mr. James Stewart Gwynne undertook a series of experiments at Pittsburgh, Pa., which resulted in the invention and improvement of several machines, amongst which is to be reckoned his "Direct Acting Balanced Centrifugal Pump," the first public exhibition of which occurred in January, 1849, at the Passaic Copper Mine. There he erected a pump 12 feet in diameter, and in 1851 obtained a U. S. patent for his invention.

1845.—Bessemer (Fig. 35). Mr. Henry Bessemer of Baxter House, well known for his several ingenious mechanical improvements, entered the lists as an improver of Centrifugal pumps, in 1845. His pump was composed of two compartments, in one of which a single suction impeller of the disc type, with radial vanes, was mounted upon a shaft; in the second compartment the impeller shaft was extended in the form of a tube, and carried hollow arms bent at the ends like those of a Barker's Mill. Steam or other elastic fluid being supplied axially to the hollow shaft, the apparatus was caused to rotate as a reaction turbine, and thus the impeller could pump either air or liquid.

The scheme, while quite inefficient, is nevertheless operative. However, it seems to be the first on record of a turbine driven Centrifugal Pump.

1846.—Andrew's Improved (Fig. 36). Mr. Andrews obtained U. S. Patent No. 4418, in 1846, for improvements in Centrifugal Pumps. These, he states in his specification, were the results of his "experience in discharging water from wrecked vessels, in which sand, gravel and other matters mingle with the fluid pumped up." He then adds, "It is well known that revolving parts of Centrifugal pumps are sometimes tubes and sometimes vanes or arms working within a fixed case, with which the suction and forcing pipe communicate. In my pump I use vanes, and I enclose them within and connect them to an additional case which revolves with them within the exterior or stationary case." The vanes, four in number, are set eccentrically on the shaft and, as designed by the patentee, are usually flat blades, as represented by the full lines of Fig. 37, but are sometimes *curved* to the forms of the dotted lines.

It was thought at the time that Mr. Andrews had certainly a fair claim to be considered as the originator of what was then known as the "Disc Pump." However, in view of the fan construction evolved by Desaguliers, such a claim is not well founded.

1846.—Von Schmidt. Hardly worthy of mention, this pump, made in New York, had its suction connection not coaxial with the casing, but to one side like the suction openings in Teral's fan.

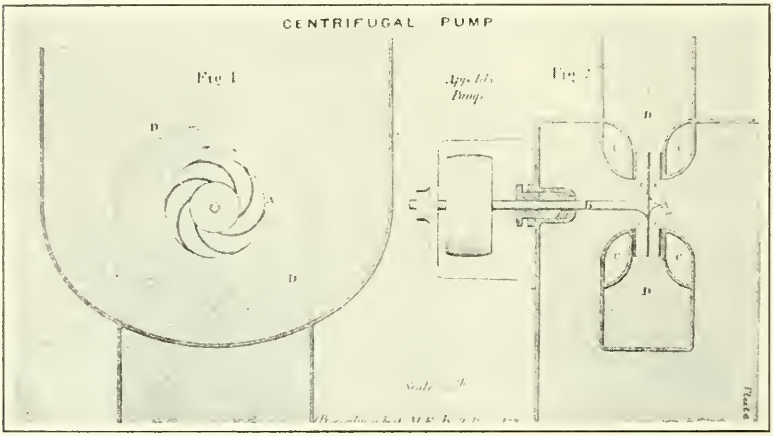


Fig. 37, Appold's Pump.

1848.—Appold (Fig. 37). In November, 1848, Mr. Appold brought out a model of a rotary pump, as a convenient means of draining marshes, and instituted a series of experiments on it with 6, 24 and 48 arms or vanes. This pump attracted considerable attention at meetings of the British Association in Birmingham, in 1849.

Some of the impellers he used had straight vanes and curved side plates, so as to produce a contracted delivery opening round the periphery. Others, as shown in Fig. 37, had curved vanes and straight sides.

1850.—Whitelaw (Fig. 38). The Practical Mechanic's Journal, published in 1850, contained several descriptions of Centrifugal Pumps devised by Mr. Whitelaw. They were mostly based, as in his first attempt, upon the Barker's Mill principle.

The most remarkable of his sketches is reproduced here in Fig. 35, because of its striking resemblance to Da Vinci's machine. According to the author,

> ‘‘* * * This is a suggestion for another modification of pump for raising water to inconsiderable heights. The sketch is a vertical section through the two discs, forming the elevating water space, the water entering as shown at *AA*, passing up at *BB*, and finally issuing in an annular sheet which is caught by the upper basis *CC*. In this pump spiral or inclined blades should be fastened in the space *BB*, between the discs, to conduct the water in a direction contrary to that in which the machine revolves, so that it may issue at the point of discharge with the least possible amount of movement in the direction of that of the pump itself. The great distinctive feature of this machine is that the water is only for a short distance in contact with the disc surfaces, being elevated above their level entirely by its accumulated momentum. If the line of discharge were made in a direction parallel with the axis of the machine—that is, perpendicularly upwards—it is abvious that the centrifugal force would throw it outward before it reached the receiver above; and to conteract this tendency the upper edges of the discs must be turned inwards to give the water a slight tendency toward the axis.’’

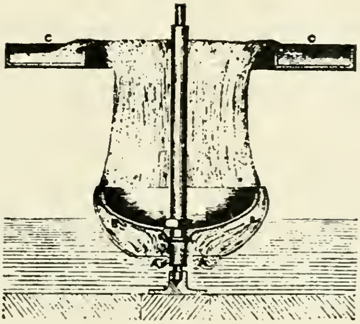


Fig. 38, Whitelaw’s Pump.

Here, as in Da Vinci’s machine, a depression is generated at the lower part of the rotor’s axis, but *now* the water is acted upon by “centrifugal forces resulting from the motion of the rotor.” The fact that positive and scientific knowledge is established and at hand is further shown in that Whitelaw does not describe existing apparatus, but rather “designs” of machines based upon known principles. He feels certain that his machines would operate well, but, of course, realizes that many points are still obscure. On the whole, his description is highly interesting.

From that time on, and for quite a period, the Centrifugal Pump progressed mainly in England and in the United States. Numerous inventors devoted their efforts towards improving the construction of the pump. Some believing that the impeller was secondary, and that the shape of the vanes was but of small importance, gave all of their attention to the casing. From this was gained the diffuser passage, brought forth by the French engineer Decoeur, which was to insure a maximum efficiency to the pump. Then this passage itself was provided with suitably curved guide vanes, which for a long time were claimed to be absolutely necessary. Others attempted to establish the true theory of the pump so as to shape the vanes in a most efficient way. So far it must be truly admitted that there is not one "published theory" that is correct, as may easily be proven.

It is worthy of note that as soon as the pump was required to handle high heads it became transformed into the multistage type. Figure 39 reproduces the drawings illustrating U. S.

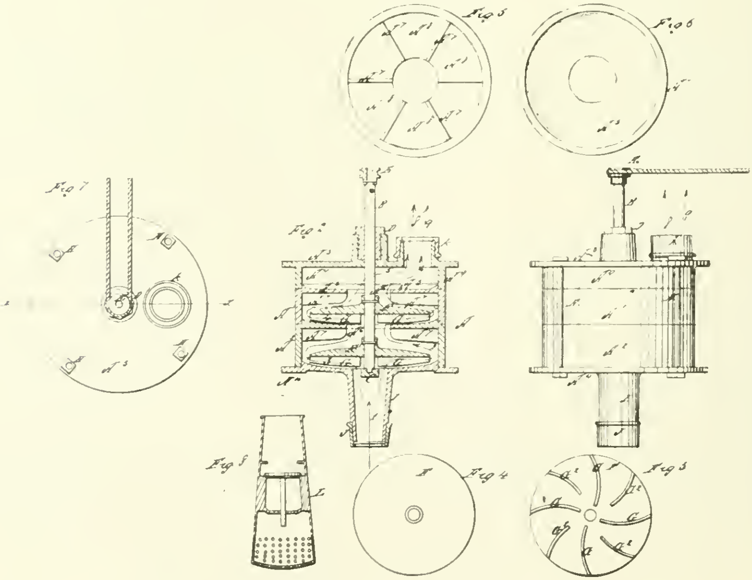


Fig. 39, W. H. Johnson's Multistage Pump.

Patent No. 4426 to W. H. Johnson, in 1846. This seems to be the first multistage pump on record. Later Gwynne of Pittsburgh brought forth the first practical pump of that type. In 1855 the French engineer, Girard, patented a multistage pump, and had one tested at Paris in 1859 by General Morin. The efficiency found was rather disappointing, rising only to 30 per cent.

General Morin, who conducted tests on the pump in London and later in Paris, states in his work on "Machines for Raising Water":

"Among the machines for raising water, which were exhibited in London, 1851, and in Paris in 1855, the most remarkable were doubtless the Centrifugal Pumps, of which there were in London three different models, which I had occasion to study as regards their efficiency. These three models were constructed upon the *same principles* as those of the *exhauster fans*, and were composed of *a wheel having straight or curved vanes*, made to rotate at a high rate of speed, and fitting very closely to the sides of *a casing having axial openings*."

It may be interesting to note that the Appold pump tested by General Morin showed a remarkable performance. In Fig. 40 the head volume curve of the test is represented in the manner customary today. Some of the observed points are somewhat uncertain, but there is no doubt as to the general form of the curve. The efficiency curve, from test, is very good and does not differ much from that of an average good make of modern pump, considering the necessarily imperfect knowledge upon which was based the design of Appold's pump.

Gwynne's pump, tested by General Morin at London in 1851, had less than 20 per cent. efficiency. The vanes were radial, and, of course, not well adapted for the work.

It is thus established that when the centrifugal pump became a practical apparatus, it was readily recognized as being simply an adaption of the well known fan blower type, such as Papin described finally in the year 1705.

The limitations of the speed of steam engines of the piston type, which for a long period were the only means at hand for driving centrifugal pumps, required the latter to be made of enormous size when designed to produce fairly high heads. Of course, in many instances pumps were driven by belting or through gearing, but this was done in every case through

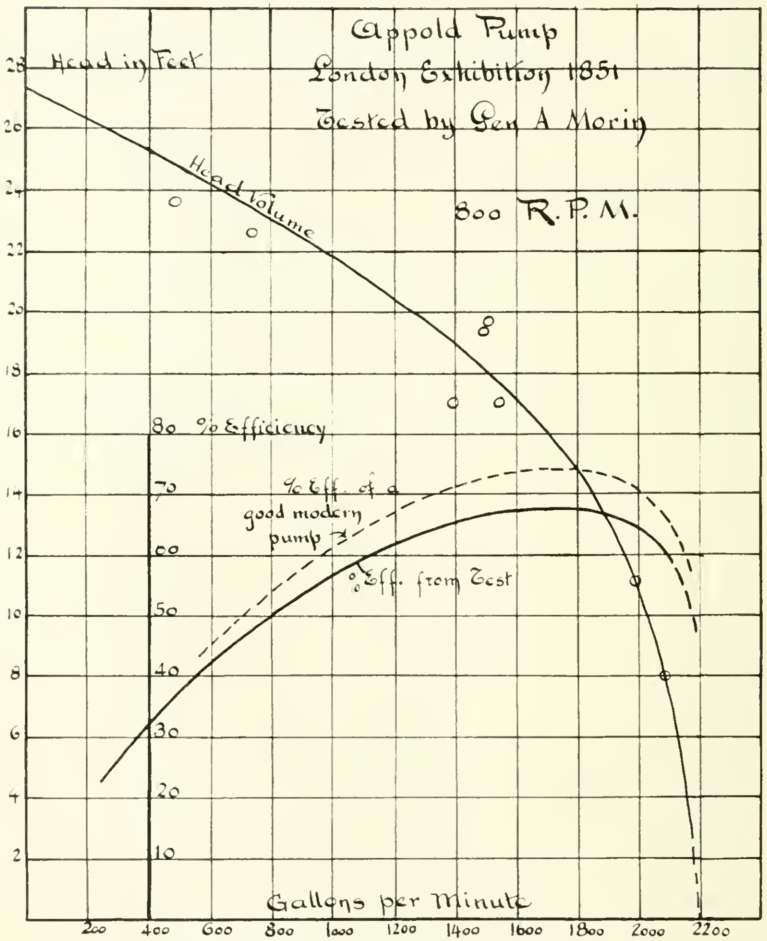


Fig. 40, Test Curves of Appold Pump.

sheer necessity. It was only when first the electric motor and then finally the steam turbine became sufficiently developed that the era of modern practice really opened for the centrifugal pump. These new driving means brought forth the high speeds and the power which had been so ardently desired by the early inventors, and particularly by Papin, who we must recognize as the real inventor of the pump.

APPENDIX.

Pumping Installation for Down-Town District, Leadville, Colorado.

In compliance with the wishes of some of the members of this Society, a brief description of pumps recently installed in the Leadville district is presented in this appendix.

The Down Town Mines Co., having decided to drain some of their shafts, placed an order through their representatives in the East, the J. G. White Engineering Corporation of New York City, with the Providence Engineering Works for four motor driven centrifugal pumps. Two of these were to be sinking pumps, lowered gradually as the water level receded into the Penrose mine shaft at Leadville, Colo. Upon reaching a level of some 460 feet from the mouth of shaft, a station was to be established, in which two stationary pumps, of the same size and pattern as the sinking ones, would be installed. Then the sinking pumps would continue their way down the shaft, gradually lowering the water level, and discharging into the stationary pumps, which in turn and without interruption, would discharge through vertical pipe columns out into the tunnel near the top of shaft.

As planned, the discharge columns were to extend down the shaft as the water receded. That is, between the pump and the lower end of column, there was provided one telescoping pipe which would follow the pump downward until a distance had been traveled which would permit of extending the column by connecting fixedly one length of pipe. At the lower end of the latter, the telescope would again be connected and the pumping process continued as before. By skillfully operating both pumps so as to at least maintain the temporary level during the extension changes, the work of draining would continue without interruption.

It was at first thought that a pumping capacity of 1500 gallons per minute against 450 feet head would prove sufficient for each unit, and the order was placed accordingly. However, the mine representatives expressed a desire to have the pumps so designed as to furnish the limit capacity for this size but without overloading the motors.

The pumping units were to be vertical and to consist each of one 8-inch, two-stage pump, capable of running submerged indefinitely, to be driven by an alternating current motor of General Electric Co.'s make, (3-phase, 60 cycles, 550 volts), located above the pump. Steel channels connected the pump and motor in such a manner that the unit could be lowered into a rectangular shaft 4′ 5¾″ by 4′ 1″, and bronze shoes attached to the channels were to slide against 4″x4″ timber guides fastened to the sides of the shaft; so that the unit had to move up and down through a space 4′ 3″ by 3′ 4″ in the clear. Ladders were to be attached to the apparatus so as to permit the operators to reach any part of it from the lower platform to the sheave at top of frame.

The cuts, Figs. 41, 42, 43 and 44, show the sinking and stationary pumps. The latter differed from the other only in that the sheave and upper platform were omitted and the lower platform replaced by a small base plate.

One of the stationary units was tested at Providence on March 9, 1915, the results being shown on Fig. 45. The limit capacity of the pump was reached at 2200 g.p.m. with a head of 370 feet. At the specified head of 450 feet, the capacity was 1760 g.p.m. One remarkable point of the test was that the pump maintained its utmost delivery without trouble through a wide pressure range extending from 80 feet to 365 feet. This eventually proved a boon in that from the very start the maximum amount of water was removed from the

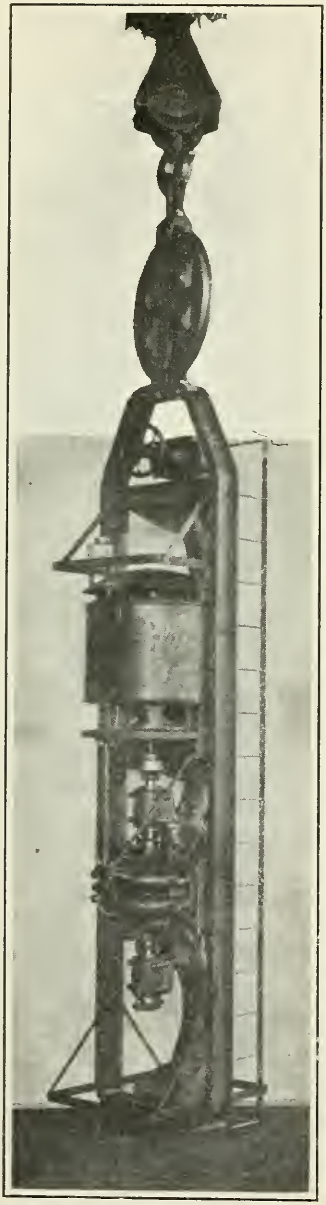


Fig. 41. Down Town Mines Co's Sinking Pump.

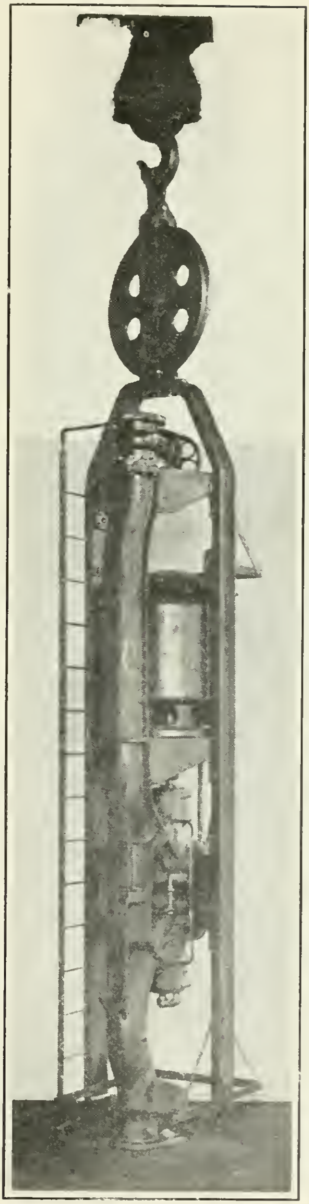


Fig. 42. Down Town Mines Co's Sinking Pump.

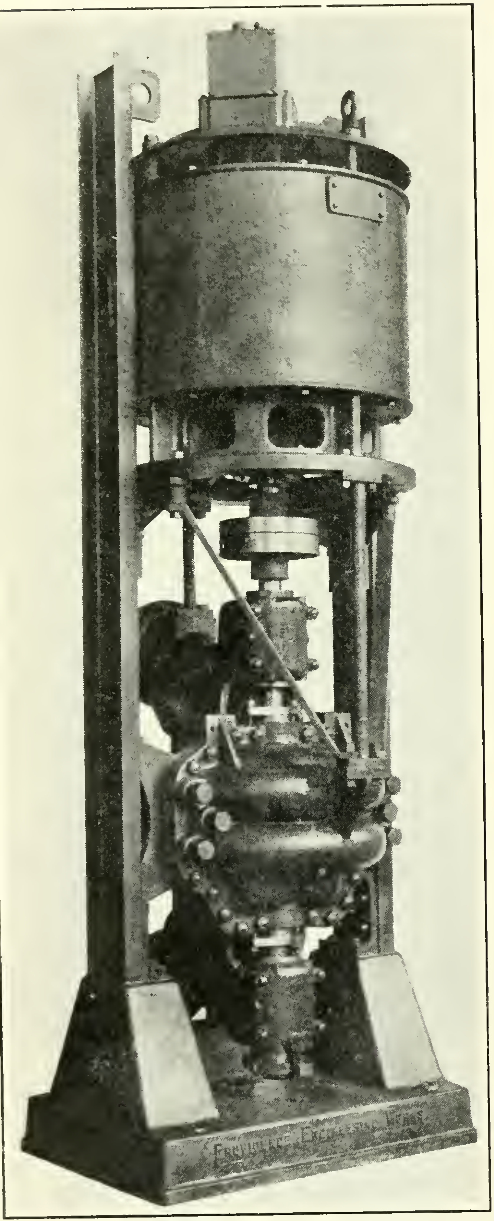


Fig. 43, Down Town Mines Co's Stationary Pump.

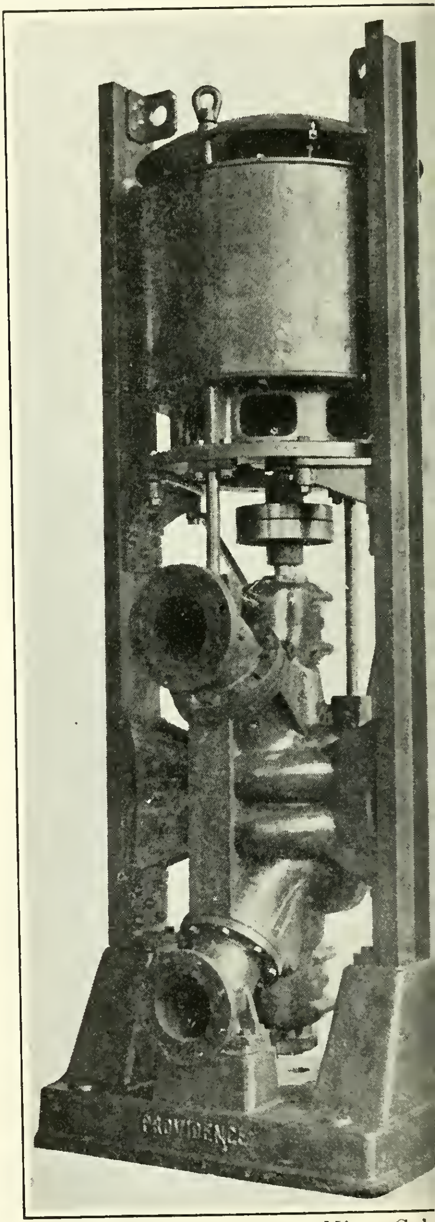


Fig. 44, Down Town Mines Co's Stationary Pump.

mine, and this maximum remained practically constant until the first station level was reached.

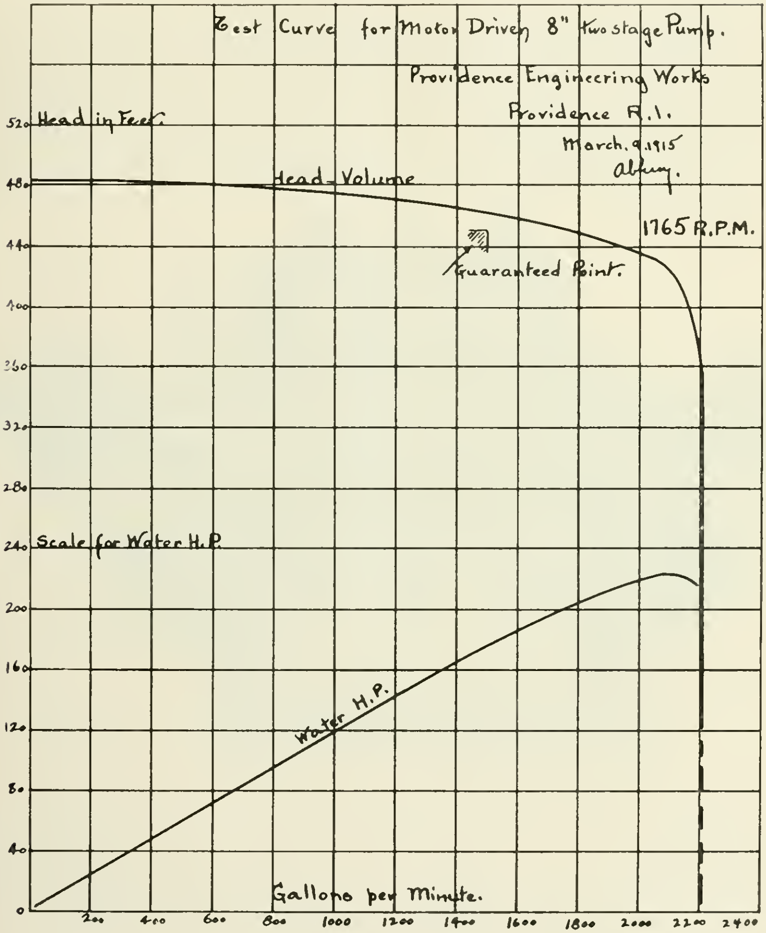


Fig. 45, Showing Test Diagram of Down Town Mines Pump.

The very construction of the unit prevented making a brake test of the motor immediately following the hydraulic test, and it was not, of course, possible to plot the efficency curve on the diagram. The electrical readings, however, showed that the apparatus was operating better than expected on the actual useful range of the pump from 1760 g.p.m. to 2200.

The contract for the pumping units stated that the writer was to supervise the starting operations at the Penrose shaft. This accounts for his stay in the Leadville district and incidentally brought about a kind invitation from the Society to present the illustrated little talk on the "Genesis of the Centrifugal Pump," before the members at Denver on April 3, 1915. The writer seizes this opportunity to renew his thanks for the very kind reception tendered him on that occasion.

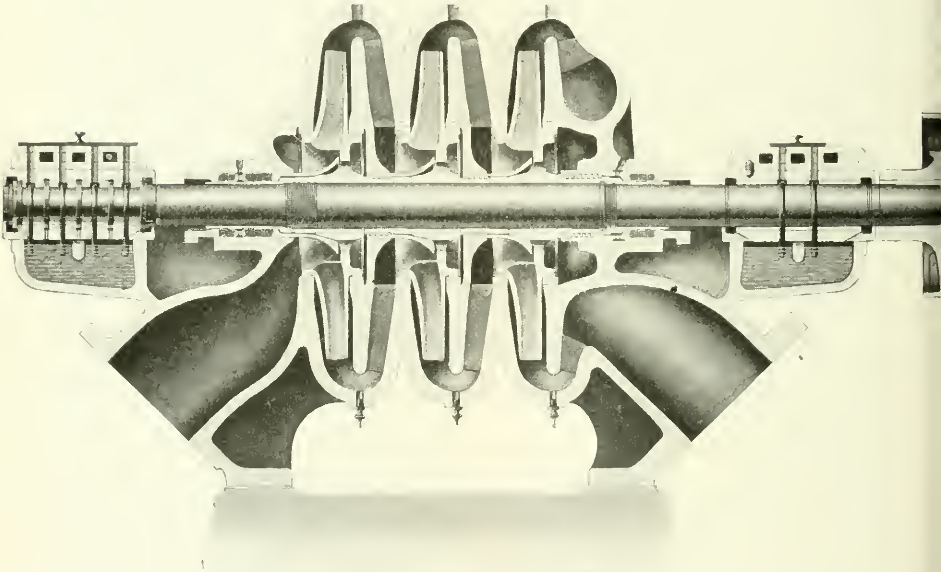


Fig. 46, Multi-Stage.

The sinking pumps have been in steady operation since May 8th; the station is now well established; the stationary pumps are co-operating with the others and the end of the unwatering work is reasonably well in sight.

The pump itself is of the standard Providence multistage type illustrated in Fig. 46; it has but two stages instead of three as shown in cut, and the bearings are lubricated with water from the discharge pipe. The bearings themselves are of lignum vitae and have no rings, since the unit is vertical.

The thrust bearing is adjustable axially and permits of maintaining the impellers securely in position relatively to the labyrinthine packing rings fixed to the casing.

The usual construction of the thrust bearing is shown by Fig. 47; omit the oil rings and replace the babbit with lignum vitae and you have the bearing used at Leadville. The thrust sleeve is of steel, is adjusted on the shaft and may be replaced at small cost in case of excessive wear.

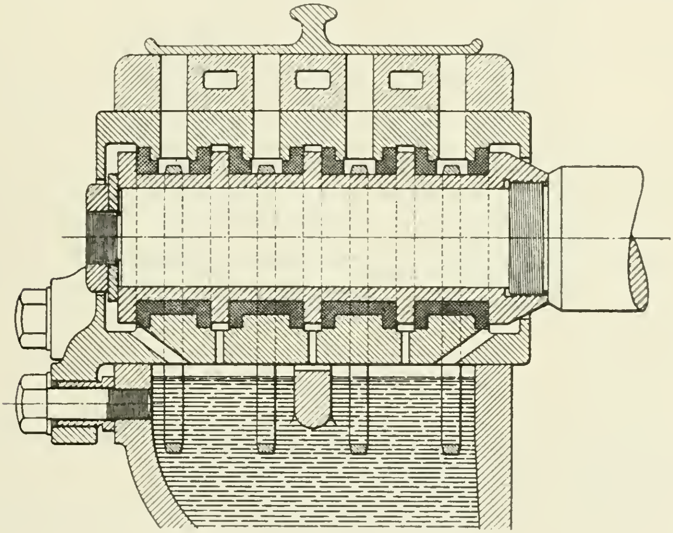


Fig. 47, Thrust Bearing.

Fig. 48 shows the impeller packing rings which are of the radial labyrinth type, permitting lateral displacement of the impeller, but having very small axial clearance so as to minimize the leakage from the discharge chamber to the inlet chamber of each impeller.

A fixed guide cone shell is located at the inlet of each impeller and serves to guide the entering water radially into the vane space. In this way the impeller hub does not come into contact with the entering water and does not, therefore, exert its usual nefarious influence in twisting the current of water.

Labyrinthine packings are also used between stages, as shown.

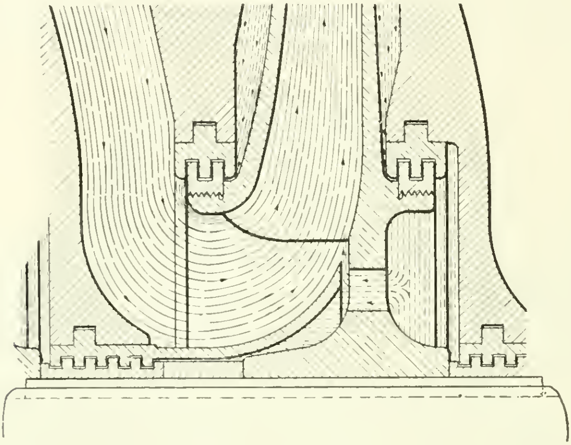


Fig. 48, Diaphragm Labyrinth.

The pump case is of cast iron; the shaft of steel; impellers, guide cones and labyrinths are of gun metal.

All wearing parts are accessible by simply removing the pump cover and, being made standard, are most readily renewable. The whole construction of the pump is based upon one main idea; that is, to facilitate to the utmost the task of the operator.

The hydraulic balance of the Providence pump is obtained in a very simple way by means of labyrinthine drums at the back of the discharge end impeller.

The stuffing boxes are packed with hemp and kept sealed through some small pipes connecting with the discharge end. At such an altitude as that of Leadville, with the barometer normally below 20 inches, it is very necessary to seal the stuffing box at the suction end.

The pump shaft is connected to the motor shaft through a flexible coupling provided with rubber bushings.

The motor shaft is supported at top on one ball bearing and is further guided by two babbitted bearings conveniently located. The lubricating system is automatic, the oil returning to a closed copper pan fixed to and rotating with the motor shaft, and in this way becoming under centrifugal pressure. This pressure then causes the oil to ascend through a stationary pipe having an intake in the pan and thence reaching to a distributing tank on top of the motor. From this tank the oil flows in an easily regulated manner to the three motor bearings and finally reaches again the rotating pan.

The current is carried to the motors through cables of special make which are lowered simultaneously with the pumping apparatus. The cables connect directly to the switchboard in the engine room. The high tension current is brought from the lines of the Colorado Power Company to the transformer house, which is located conveniently close to the engine room.

The pumping apparatus is remarkable by its compactness. The available size of the shaft was so small that grave doubts were entertained at first as to the feasibility of the undertaking. The apparatus having proven its ability to meet the hydraulic and power conditions, the operators set to work with great will and, thanks to their experience and highly intelligent efforts, met successfully one after the other the thousand and one problems that beset their novel task. The retimbering of the shaft as they proceeded through soaked soft ground was not the least of the difficulties. The work is now so well advanced that the hopes of the operators seem in very good way to be realized in the near future.

PROCEEDINGS OF THE COLORADO SCIENTIFIC SOCIETY
VOL. XI, pp: 103-176.

A SERIES OF TREATISES ON THE RARE METALS.

By Dr. Herman Fleck.

(Read at the meetings of the Society on the following dates : Tungsten, Oct. 2nd, 1915; Molybdenum, Dec. 4th, 1915; Vanadium, March 4th, 1916 and Uranium, May 6th, 1916.)

What is a rare metal? The answer to a now popular question has no special importance but an answer to any question seeks to give satisfaction and therefore it may be well to discuss it.

About ninety-nine per cent of the earth's crust is made up of the ten elements: oxygen, silicon, aluminium, iron, calcium, carbon, magnesium, sodium, potassium and hydrogen.

This leaves nearly seventy elements which go to make up a remaining per cent. Yet most of these are not considered rare. Sulphur, barium, lead and zinc are not rare elements.

Two considerations may be brought to bear upon the term, and these are: the relative proportions of the elements remaining in this one per cent. and the commercial popularity an element has achieved.

The former consideration may be sensed in a broad way. For instance, about five thousand tons of tungsten are produced annually. This is infinitesimal compared to the billions upon billions of tons of earth's crust already fairly well investigated without promise of marked addition beyond what is known of the present extent of tungsten areas. It is infinitesimal compared to that one per cent. to which tungsten belongs.

With regard to the latter consideration, twenty years ago not many students of chemistry had the good fortune to see the metal or its compounds. But today tungsten steel and tungsten lamp are on every tongue and the metal has ceased to be a curiosity.

Molybdenum and vanadium became popular through their connection with certain other properties imparted to steel; and had it not been for the interest created by the physics and therapeutics of its associate, radium, uranium and its compounds would have remained in obscurity.

These are therefore no longer types of ultra rare metals of which gallium and germanium are good examples, but lie, for the above reasons, between the ultra rare and the common metals.

Whenever a commercial use stimulates a demand for a relatively obscure metal there will follow a diligent search for new occurrences and a more thorough investigation of those already known. The eye is urged to be on the lookout and an increased production is sure to follow. This has been the history of the rare metal. No doubt others will some day fall from the class of ultra rare to the rare.

TUNGSTEN.

HISTORICAL.

The word is Swedish. It means heavy-stone. Wolfram, from the Latin wolframum is still widely used and furnishes the chemical symbol W. The ore was known to Agricola in the sixteenth century. Both wolframite and scheelite were considered tin ores up to the middle of the nineteenth century.

In 1781 that remarkable chemist, Scheele, recognized the latter to be a lime salt of a peculiar acid. And in the same year Bergman in the quaint phlogiston way pronounced this acid a metallic calx. In 1783, Jose and Fausto d'Elhujar proved the existence of the same peculiar acid and by the action of charcoal upon it, in a carbon crucible at a high heat, they made metallic tungsten. Of course, they viewed the operation as an introduction into the calx of phlogiston in which carbon was believed to be particularly rich.

It is to be noted that a process in use today in making powdered tungsten is rounding into a century and a half of its existence.

In 1848 Oxland proposed a method for the decomposition of tungsten ores by fusion with soda ash and sodium nitrate. Thus the complete basis of a modern method for the preparation of tungsten was evolved nearly seventy years ago.

The history of tungsten is resplendent with the names of brilliant investigators such as Klaproth, Vauquelin, Richter, Berzelius, Wöhler, Marignac, Bloomstrand and Roscoe.

In passing let me quote a passage from a publication by Sir Henry Roscoe. It is this: "Many suggestions have been made for the improvement of tool steel by the addition of tungsten, inasmuch as this is said to improve the quality, hardness and tenacity of the metal; but it appears that this application has not proved commercially successful"—this in 1890.

No doubt the above has reference to a steel manufactured by a Mr. Mushet and known since 1850 under the name of mushet steel. It consists of iron, manganese 1·5% and over, carbon 1·5 to 2% and tungsten 3 to 10%. Tools made of this steel were not of great advantage over carbon steel. The addition of chromium and elimination of manganese later added to the improvement; but not until Taylor and White in 1900 patented a process for the heat treatment of this steel did the high speed qualities result, which have given rise to the industrial development of tungsten noted today.

Not much commercial interest is recorded for tungsten in the United States until 1900 when about forty tons of high grade ore were shipped from the Boulder County Ranch. Half of this was sold for $60.00 a ton or $1.00 a unit. The mineral had been found on this and surrounding property as early as 1870 by Samuel P. Conger; but it was not recognized for many years as a tungsten mineral, much less as a forerunner of one of the richest tungsten fields in the world. It is stated that an over-excitement due to foreign manipulation caused a production much in excess of the market demand in 1901 and 1902. Then after absorption of the excess output a steadier production and market followed together with a rise in the price. A steady increase in output under developing conditions of market prevailed until 1907. In the early fall of that year tungsten sold for $11.00 a unit and a few sales were reported at $13.00. Then suddenly the financial depression of that year lowered the prices to $5.00 and $6.00 a unit and a severe set back resulted from which a slow recovery was made which lasted several years.

Properties of Tungsten.

Tungsten in its purest form, free from carbon and iron has the following properties: It is a steel-gray metal; specific gravity 19·39 to 20·2; melting point 3100° C. ±60° C.; specific heat ·0358; co-efficient of expansion $4·3 \times 10^{-6}$; tensile strength 322—427 Kg. per sq. mm. It can be swaged and drawn into fine wire. At ordinary temperature it is not affected by air; but at elevated temperature it burns to oxide and in pure oxygen with evolution of heat and light. It is not attacked at ordinary temperature by hydrochloric or sulphuric acid. The effect of nitric acid is slow and aqua regia does not act rapidly, in both instances, no doubt due to a self protecting coating of the acid insoluble oxide. Fused alkalies attack it, liberating hydrogen. Chlorine gas attacks readily, forming brilliant colored chlorides.

The above applies closely to the powdered tungsten. Massive tungsten is similarly affected but with less vigor.

MINERALS.

Those of commercial importance are: Wolframite, Hübnerite, Ferberite and Scheelite.

Wolframite is an iron manganese tungstate $(MnFe)WO_4$
An anlysis is:

Tungsten oxide (WO_3)	76·00	per cent
Ferrous oxide (FeO)	16·00	“ “
Manganous oxide (MnO)	7·70	“ “

Ratio of iron to manganese may vary 9:1 to 2:3.
Form: massive granular; crystals submetallic.
Color: black to gray black.
Streak black; brownish black; grayish black.
Hardness: 5-5·5.
Specific gravity: 7·1-7·55.
Cleavage good.

Hübnerite is a manganese tungstate $(MnWO_4)$
An anlysis is:

Tungsten oxide (WO_3)	75·58	per cent
Manganous oxide (MnO)	23·40	“ “
Ferrous oxide (FeO)	·25	“ “

Form: massive granular; crystals submetallic.
Color: black to brown red. Black to dark grayish or brownish black, brownish red, hair brown.

Hardness: 5-5·5.
Specific gravity: 7·2-7·5.
Cleavage perfect.

Ferberite is an iron tungstate ($Fe\ WO_4$)
An anlysis is:

Tungstic oxide (WO_3)	75·68	per cent
Ferrous oxide (FeO)	24·47	" "
Manganous oxide (MnO)	·12	" "

Form: massive; massive granular; crystals submetallic.
Color: black; brownish black.
Streak grayish black.
Hardness: 4-4·5.
Specific gravity: 7·1-7·5.
Cleavage perfect.

Scheelite is a calcium tungstate ($CaWO_4$)
An anlysis is:

Tungstic oxide (WO_3)	80·6	per cent
Calcium oxide (CaO)	19·4	" "

Form: coarse granular; crystalline.
Color: brownish white; pale yellow; gray or green.
Hardness: 4·5-5.
Specific gravity: 5·4-6·1.
Cleavage good.

Naturally variations in chemical composition occur in these minerals; but these are rather of scientific than technical value.

Chemical treatment of the four minerals for analytical purposes does not vary much. They are all decomposed by digestion with aqua regia when finely divided, forming a more or less hydrated tungstic oxide, bright yellow in color.

When there is much gangue material the yellow solution of ferric chloride will lend a very deceptive yellow color to the gangue. In such cases the gangue should be well washed with water. A good additional test is that made by adding a few pieces of zinc to the residue, followed by somewhat dilute hydrochloric acid. Any yellow oxide is hereby changed to a lower blue one making a delicate test.

OCCURRENCES OF COMMERCIAL IMPORTANCE AND CHARACTERISTICS.

The United States at one time led in the production of tungsten ore; but is now rivalled by Burma and Portugal. It is estimated that Boulder County furnishes eighty per cent. of the United States' production and twenty per cent. of the world's supply. No other single district has that distinction, I believe. The ore here is ferberite.

The producing area is about eight miles square and is embraced by an irregular flattened circle extending from Rollinsville south, to Sugar Loaf north and from Cardinal west to Magnolia east. It is reached by the Colorado and Northwestern Railroad, fifty-nine miles from Denver by a northern route, and by the Denver, Northwestern and Pacific railroad, forty-two miles from Denver by a southern route. In actual distance the field lies about thirty miles northwest of Denver and about eleven miles west of the City of Boulder. No railroads run into the field proper; but there are good roads for a few miles hauling.

The area lies in the slope between the main range and the plains and its geology is characteristic of that region. The most important rocks with reference to tungsten are: granite and granite gneiss, intersected by dikes of granite from three to twenty feet in width. The mineralized veins are impregnations of acqueous origin in fissures in the granite. The general trend of their strike is from north to northeast. Their dips, northwest and southeast. The older idea that the ore was "bunchy" has had to be modified by the occurrence of deposits of surprising distance both horizontally and vertically. It is described that the deposits continue well formed to a depth between five hundred and six hundred feet, with every indication of continuance.

In nature the ore is varied. It usually accompanies a secondary and sometimes a tertiary brecciation the cementing agent being chalcedony, "hornstone," or ferberite or both.

Variations in ore shade from pure chalcedony to gray simultaneous deposition of chalcedony and ferberite to crystals of ferberite of remarkable purity. A common variety is called "peanut candy" ore, a term which does not lack descriptive power for the highly brecciated variety. In good specimens it may contain thirty to forty per cent. tungstic acid and in others as low as one-half per cent. Other forms show pure crystals filling crevices in granite and pegmatite. Crystalline incrustations covering pebbles and irregular masses of wall rock are also prominent.

These varieties have much bearing on the recoveries made in milling practice.

Second in importance in the United States is the Atolia district, San Bernardino County, California. The ore here is scheelite. Atolia lies five miles south of Randsburg. The veins lie in schist and granodiorite. The scheelite is found with calcite and quartz in crushed and partly silicified country rock.

Portugal leads Europe in production of tungsten in the form of wolframite. The province of Beira Baixa, the east central portion, largely claims this distinction. The associated minerals are tin ore, arsenopyrite and pyrite in quartz.

Surprisingly productive have Burma and the Shan States become. From a comparatively meagre output in past years, the region has recently headed the world in production. The ore is massive wolframite in Burma and it occurs in nodules and granules, together with tin ore in an easily worked alluvial deposit. The parent bodies are as yet untouched and for greater part, unexplored. They lie in the mountain range of intrusive granite which constitutes the back bone of the Malay peninsula. The bodies farther to the south have the distinction of being the greatest tin bearers in the world. The proportion of tin to wolframite lessens but is still present in workable quantities. These bodies are divided into three divisions, depending on their contents: First, wolframite-quartz; second, cassiterite quartz; third, wolframite greisen. The total cost of production of one ton of sixty-eight per cent. concentrate is given at $313.79 and the price paid, laid down in England is $496, leaving a net profit of $182.00.

South America has producing mines in Argentine, Bolivia, and Peru. In Argentine the provinces of Cordova and Mendosa, centrally situated, yield an excellent wolframite. In Bolivia the mineral is found to the west and southwest in the Departments of Orura, Cochabamba and Potosi. Here again the ore is wolframite, containing from five to twenty per cent. of tungstic oxide (WO_3). It occurs associated with tin, bismuth, copper and silver. The mines are small, about thirty in number and the ore is concentrated to 60-70% oxide.

Peru is also making a constantly increasing output of hübnerite concentrated from an ore averaging three per cent. tungstic oxide associated with high copper and silver contents. The veins average thirty-two inches and the richest deposits follow a contact between a granite base and superposed strata of slate and quartzite.

Queensland, Australia, produces wolframite in quartz and feldspar but the deposits are said to be giving out.

In New South Wales both wolframite and scheelite are produced extensively. Victoria produces wolframite in paying quantities. New Zealand is a steady producer of scheelite. Japan produces wolframite. Central Halifax, Nova Scotia, produces scheelite associated with ankerite, arsenopyrite and pyrite.

These constitute the principal occurrence of tungsten minerals at present but we may expect to hear of activity in a considerable number of other localities this year.

CONCENTRATION.

We are more familiar with the practice of ore-dressing in Boulder County than elsewhere.

It was mentioned that the brecciated nature of much of the ore offered difficulties which in early days were lightly passed by, permitting about half the ferberite to pass into slime ponds. Of course, larger recoveries are known to have been made but this was no doubt on ores of more favorable structure.

The problem is affected by a two-fold difficulty. Namely the friability of ferberite whose perfect cleavage has been noted and which produces thin plates of mineral, all too readily slimed by the action of stamps which are thought necessary to release the finer particles inclosed in simultaneously deposited silica. In a measure this has been overcome by a better demand for concentrates running from twenty-five to forty per cent. and by contrivances introduced to handle the slimes rejected in older practice.

In the former instance the increased density of the hornstone due to enclosed ferberite allows coarser crushing and subsequent separation from the gangue.

In the latter instance modern sliming tables and canvas tables prevent much of the ferberite, unavoidably slimed, from going to waste.

Again with the first instance in view, still coarser crushing, sizing and jigging followed by full use of present practice has been suggested but apparently without producing change of method generally.

As it is, with increased use of the expedients mentioned, a recovery of sixty-five per cent. with more refractory ores is made possible and recoveries of eighty-five per cent. are common.

An example or two will suffice to illustrate the practice in use.

1. The ore is passed over a 2-inch grizzly from which the undersize passes to the stamps and the oversize to a 7x10-inch Gates crusher, thence to the stamp battery. The latter consists of 20 stamps of 1000 pounds each with a six inch drop from which the ore, crushed to twenty mesh, passes to a special classifier, which delivers the coarse to two number five Wilfley

tables, the middlings to one number three Wilfley table and the slimes to two number three Wilfley tables. Concentrates from the coarse from one product and concentrates from the middlings and slimes are combined into a second product.

The tailings from all tables are tanked and distributed to four Wilfley slimers from which the tailings are rejected, the concentrates combined to a third product and the middlings sent to an additional Wilfley slimer where a final concentrate is collected. The capacity is twenty-five tons in twelve hours and the average concentration is 15:1.

2. The ore is passed over a 2-inch grizzly, undersize to stamps, oversize through a 7x10-inch Gates crusher to battery, consisting of 10 stamps, 760 pounds each, 9-inch drop, 64 per minute and through a 12-mesh screen. Two number 4 Wilfley tables receive it making a high-grade concentrate, tails going to a settling tank and thence to classifiers. The coarse is sent to a 4x12-foot Frue vanner, the middlings and slimes to two 6x12-foot Frue vanners. The concentrates from middlings and slimes are combined. The tailings from the coarse are put through a Huntington mill with 60-mesh screen and then to canvas tables. The tailings from the other two vanners go to a V-shaped settling tank from which the pulp is treated by four vanners, and the overflow goes to canvas tables. The latter, two sets 12x40-feet each, have a slope of one foot in twelve inches.

A characteristic analysis of a high grade concentrate is:

Tungstic oxide	59·99	per cent
Iron oxide	32·57	“ “
Sulphur	·00	“ “
Manganese oxide	1·02	“ “
Phosphorus	trace	
Silicon dioxide	8·32	“ “

Depending on the mine and class of concentrate, deviations arise in composition, but outside of the relative change in proportion of ferberite and silica no marked differences occur. Sulphur may rise to over one and one-half per cent. It is seen that the mineral proper constitutes nearly ninety per cent. of the product.

Nearly all the mills do custom work and settlement varies from purchase of ore outright on a sliding scale to a fixed price of \$3.00 to \$4.00 a ton for concentration and purchase of the resulting concentrate at market price. A sliding scale is graduated from one to four per cent., five to nine per cent., etc., and in terms of cents per pound of tungstic oxide present in the ore or concentrate up to sixty per cent. Market price changes, of course, rearrange the price scale but a fair idea of a basis is seen in the scale of December 1, 1912, when \$7.50 was the prevailing figure per unit.

WO_3 in ore.	Price per lb. WO_3
1- 4	5-11c
5- 9	15-19c
10-14	20c
15-19	23c
20-24	25c
25-29	26c
30-34	27c
35-39	28c
40-44	29c
45-49	30c
50-54	32c
55-59	34c
60	37½c

Magnetic separation has been tried with some success.

Where the ore contains arsenopyrite or pyrite or both, direct treatment with electrostatic machine has proved successful experimentally. Usually in practice wet concentration is first employed and the dried mixed concentrate is roasted to render magnetic the contaminating minerals, after which they are withdrawn in the magnetic field of a separator. Such is the case with Nova Scotia scheelite. Or as in the case of wolframite and tin ore a differential separation by magnetic fields of varying intensity may be used. The Cornwall tungsten ores are thus treated, making a separation of the above from iron oxide and then from one another. That is a matter to be determined, of course, for each variety of ore and there are many of them.

PREPARATION OF TUNGSTIC METALS.

The metal is prepared in two forms: powder and ferro-tungsten alloy. Much discussion has arisen regarding the advantages of one over the other, especially with reference to the relative waste incurred during introduction of each form into the steel bath. Apparently no decision has been reached, since both forms are manufactured, although about eighty-five per cent. of the tungsten is made into ferro-alloy. The introduction of powdered tungsten into the bath by means of enclosure in steel tubes, in order to prevent oxidation of the tungsten, has been described. The manufacture of powdered tungsten first demands a preparation of tungstic oxide (WO_3), from the ore. This is accomplished by grinding the concentrates very fine in tube-mills after which fusion on a reverberatory hearth with sodium carbonate in form of soda ash and a small proportion of sodium nitrate is made to disintegrate the mineral. The hand-rabbled mass is then drawn, crushed and leached with hot water. The sodium tungstate so formed is readily soluble while the iron remains as insoluble ferric oxide and silica, for the greater part, as insoluble sodium silicate. Loss from formation of insoluble sodium meta-tungstate may be largely overcome by treatment of the insoluble residue with a solution of caustic soda which transforms the meta into the normal tungstate. Indeed, a method is published whereby the normal tungstate is purposely converted, by careful addition of acid, into the insoluble meta tungstate which is then filtered off, washed, and decomposed by hydrochloric acid. The rather concentrated solution containing the sodium tungstate is heated and poured into hydrochloric acid which precipitates the yellow tungstic acid. The latter is filtered and washed in acid-proof presses and then dried.

Reduction of the oxide is accomplished by mixing intimately some pure form of carbon such as charcoal or petroleum coke and the charge is pressed into graphite crucibles which are heated in coke furnaces to a high temperature. A rather coarse, steel-gray dense tungsten results, which, with care, may have its carbon contents kept within one per cent.

Ferro-tungsten, the second product, is mostly made from the concentrate direct by electric-furnace treatment. It contains from fifty to eighty per cent. tungsten. Many different reducing materials are recommended. Carbon in the form of coke is the common reducing agent. Lime and silica are added to form a suitable slag and sometimes fluorspar is added to aid liquefaction. Hematite is used subsequently as a decarbonizer. Other procedures call for silicon, ferro-silicon, aluminium and even titanium as reducing agents in order to reduce the carbon contents of the metal.

Uses and Products.

The principal use for tungsten, as already mentioned, is in the manufacture of high-speed tool-steel. In order that this term may be better understood a comparison with ordinary high-grade carbon-steel is used.

When "the standard cut" is employed, it means that a tool fastened in the slide-rest of a lathe is made to turn off a chip of soft cast-iron or mild steel, 3/16x1/16 inch measured on the object being turned. When the radial depth of the cut shows a reduction of 1/50 of an inch the life of the tool is ended for that test. The variable is the rate of revolution and determines the speed, that is the number of feet of the body being cut passing the tool edge per minute.

Under this standard a tool of ordinary carbon steel failed at a speed of fifteen feet per minute. A tungsten-steel tool withstood ninety feet per minute and its edge became dull red in diffused daylight.

Typical proportions in high-speed tool-speed are:

Manganese	0·15 to 0·35	per cent
Tungsten	5·00 to 17·00	" "
Chromium	1·00 to 2·50	" "
Carbon	0·4 to 0·85	" "

A striking instance of the efficiency of this kind of steel is an account of a strike in the machine shops of one of our large railways, caused by the reduction of the working force in the machine shops when tungsten tool-steel was introduced.

The pure metal has been adopted widely in the manufacture of the tungsten lamp, the economy of which has forced replacement of other filaments. From the standpoint of consumption of metal this use would appear insignificant. Granted that a recent statement, to the effect that ten million lamps of this kind are made yearly, is correct, an average weight of one hundred milligrams per lamp would mean an annual consumption of one thousand kilograms or somewhat more than a ton of metal. A more liberal allowance in number and weight would not make a great difference in the estimate.

The process is interesting, however, especially since numerous improvements using small quantities of metal will no doubt in the end mean much more for consumption. The older type of lamp used brittle filaments containing carbide, arising from the colloidal mixtures of ammonium tungstate, or tungstic oxide and starch for example. These were pressed through dies and the thread so produced after drying was heated in a current of hydrogen. It was then sintered in a neutral atmosphere by a strong electric current.

The modern practice produces a strong filament which increases the life of the lamp materially.

A very pure oxide free from iron is prepared from a pure tungstate or from the oxychloride and water, or by repeatedly boiling the oxide with hydrochloric acid. This is then reduced to metal in an atmosphere of hydrogen in an electric furnace. The metal is therefore carbon-free. It is placed in a mould and swaged, making a bar which is compact but easily broken. It is then heated in hydrogen, by its own resistance to a strong electric current, whereby the metal is made into an ingot which is rolled and finally drawn into filament wires.

Further uses for tungsten are as follows: Phonograph record needles, spark plugs, contacts, and X-ray targets.

Both chemically and physically, the metal and its alloys possess properties which will undoubtedly suggest other uses and novel ones.

PRODUCTION.

The world's production of tungsten in 1913 amounted to ten thousand metric tons of sixty per cent. concentrates of which the United States produced one-thousand, five hundred and twenty-five tons, and Boulder County nine-hundred and fifty-three tons, the remainder presumably coming mostly from California.

Burma and the Shan States produced twenty-seven hundred tons in 1913 against nineteen hundred tons in 1912.

The remainder may be nearly accounted for if it is assumed that other countries equalled their 1912 output which is as follows:

Portugal	1332	tons
Argentine	638	"
Bolivia	497	"
Peru	211	"
Spain	200	"
British Isles	207	"
Japan	250	"
Australia	360	"

Assuming an average value of $450 a ton the 1913 production reaches the sum of four and one-half million dollars.

The United States production would claim $640,500 as its share from one-thousand, five hundred and twenty-five tons, with an average of $420 a ton, or seven dollars a unit.

It is certain that in production from all sources and in price paid in consequence of the demands arising from the present war the year 1915 will eclipse all records in tungsten history.

MOLYBDENUM.

HISTORICAL.

The name molybdena, now applied only to the metal molybdenum and its compounds, really means lead. That is because the Greeks used the name for the latter as well as for all dark metallic sulphides. The resemblance between lead, molybdenite and black lead or graphite especially, is shown by ancient lack of discrimination between them and our retention of the confused term "black lead" and "lead pencil." No doubt, when better means of determination arose the easiest one to identify, lead, was eliminated; but the difference, superficially slight, between graphite and molybdenite did not permit classification until late in the phlogiston period. The name molybdenum for many centuries, therefore, pertained to graphite and molybdenite which were considered identical.

It is interesting to note how these two were finally distinguished. By the action of nitric acid upon molybdenite, Scheele in 1778, three years before his work on tungsten, showed that there were formed sulphuric acid and a white acidic earthy substance which we term molybdic acid today. In 1779 Scheele, in another treatise on plumbago, firmly established the difference between the two minerals, theretofore confused. In the phlogiston way the earth was considered the calx of a metal and on this theory, in 1790, facts were made known regarding the first preparation of the metal by Hjelm, who, prompted by the current belief that carbon was rich in phlogiston ignited the acid oxide of Scheele in a graphite crucible with carbon. The resulting gray metal must have contained considerable carbon. The process is commercially used today.

PHYSICAL AND CHEMICAL PROPERTIES.

Powdered molybdenum, the first variety made, is best prepared from the pure oxide heated in a current of hydrogen. It is a gray powder which when compressed takes on a metallic luster. The specific gravity is 9·0 and the melting point 1800-2000° C. The metal in this form is rather easily oxidized at elevated temperatures. Dilute acids have no effect upon it. Strong nitric acid oxidizes it. So does concentrated sulphuric acid and at the same time there are formed lower oxides which are soluble in the acid with formation of a deep blue color. The halogens attack it with formation of more or less volatile variously colored halogen and oxy-halogen compounds.

The massive metal on account of less surface exposure is less active toward re-agents.

The trioxide is volatile at high temperatures.

Minerals and Ores.

There is only one mineral of importance, namely, the disulphide MoS_2, called molybdenite.

The composition is: Molybdenum 60%.
Sulphur 40%.

The mineral crystallizes in scaly hexagonal prisms.

Hardness: 1-1·5.

Specific gravity: 4·44-4·8 (Graphite about half of this).

Luster: metallic.

Color: lead-gray; blue to purple tinge; opaque.

Streak: blue-gray on paper; green-gray on smooth porcelain surface (distinction from graphite).

Cleavage: basal; perfect.

Molybdate of lead occurs in nature. It has been used commercially for the production of molybdenum, but not to an important extent. It's formula is $PbMoO_4$ and theoretically it contains only 26·15 per cent. molybdenum. The latter metal is more difficult to obtain from this mineral called wulfenite.

The composition is: Molybdenum trioxide 38·5%.
Lead oxide 61·5%.

Hardness: 2·75-3 (brittle).

Specific gravity: 6·03-7·01.

Luster: resinous.

Color: wax-yellow to orange-yellow.

Streak: white.

A third variety of molybdenum mineral is the tri-oxide, called molybdenum ochre or molybdite. It usualy accompanies molybdenite, the sulphide, as a yellow powdery incrustation, which has resulted from exposure of the sulphide to oxidizing influences. Sometimes it is mistaken for carnotite, although the associated rocks are entirely different. Commercially it has no important bearing except, perhaps, to the prospector.

Localities of Molybdenum Occurrence.

In commercial quantities the ores occur widely distributed. Localities of present or prospective importance are: Australia, Norway, United States, Canada, Mexico, Japan, Sweden, Cornwall, Austria, Scotland, France, Russia, Germany, Peru, The Transvaal, Natal and doubtless others.

In Australia the distribution of importance is limited to the Eastern Division of New South Wales and New England Division, Chillagoe District, of Queensland. In New South Wales there are twenty-two scattered localities, of which the most important are the Whipstick and Jingera mines in the Pambula division and the mines of Mr. V. Sachs, near Glen Innes at Kingsgate and also at Bolivia and at Tenterfield in the Deepwater Division. The producing mines are near the north-east narrowed end of New South Wales, not remote from the Queensland border. Kingsgate has shipped ore since 1885, when two tons were sold. In 1888 the same amount was shipped. From 1894 to 1898 thirty-six tons were mined, but the market became so unsatisfactory that mining practically ceased. From 1901 to 1905 the mines had their fullest development.

In Queensland north of this district lie Wolfram Camp, Wolfram and Bamford. The district has become equally important with the above described as a molybdenum producer. In 1913 it produced 66 tons out of 145 tons from all Australia, of commercial ore, presumably 80 per cent. molybdenum sulphide. No other deposits in the known molybdenum world have been so famed as the Australian, in extent and quality of ore.

In Norway, the Fjotland district, on the south and southwest coast, possesses a triangular belt of molybdenum-bearing rocks. The nature of the ore gave much discouragement at first, but it was through exploitation of English companies, notably Blackwell Sons & Co., of Liverpool, that Norway ranked next to Australia in importance. The principal mines, The Storknaben at Flekkefjord, are reported to have been worked out. However, since 1902 Norway has produced 25 to 30 and even 40 tons of molybdenite a year.

Up to the present time these two countries have supplied the world with molybdenum under conditions which were not favorable to exploitation in the United States and Canada. The result is that the quantity of molybdenum ore produced in either country up to the present time is negligible; yet under more favorable conditions such as prevail at present in price and market, molybdenum properties in both countries are active.

The area of distribution in the United States is very great. The oldest known deposits lie in the southern part of Maine, at Cooper, Washington County. Actual operations, mining and milling, took place here in 1904, but these ceased after a brief run. Near-by at Catherine Hill, Tunk Pond, Hancock County, there is another deposit of very considerable area, which from time to time has received attention. The mineral-bearing zone is described as several hundred feet in width and three-quarters of a mile long.

Arizona, in the past, about 1904, has shipped some wulfenite from the mine dumps of Pinal County copper mines on the Rio San Pedro at Mammoth and Troy. The sulphide occurs in the Santa Rita and Patagonia Mountains in the southern part of the state at Helvetia, Madera Canon, Providence Canon, Duquesne and San Antonio Canon. Considerable importance has been given a deposit in Chelan County, Washington, thirty miles from the head of Lake Chelan. The molybdenite occurs in ramifying seams in an ore-body consisting of a two-foot quartz vein, which outcrops for nine hundred feet.

In California fifteen localities are reported in which ore occurs in commercial quantities, but difficulty of concentration has proved a hindrance to development. Two and one-half miles northeast of Randsburg there are eighteen claims. One lode it is said, is to be traced for two miles, is 30 feet in width and samples (average?) show 5·5% molybdenum. The contact is lime and schist.

A strange occurrence of molybdenum was found by the author in July, 1910, while examining the alkali waters of Soda Lake in San Bernardino County, for the Pacific Salt and Soda Company. Upon saturating several gallons of this water with hydrogen sulphide, the color was changed to a yellowish red. This suggested the formation of a sulpho salt. Upon acidifying, a brown sulphide was actually precipitated. This was examined for those rare metals whose dark sulphides form sulpho salts, and molybdenum was identified.

It is not known whether this is purely a local condition, but presumably it is. Molybdenite has been reported in the granites of the surrounding hills. The amount of molybdenum found, calculated as molybdic acid, was 9·105 grain per gallon. The presence of a soluble molybdate in the ash of a Belgian coal is another freak occurrence.

Colorado has several well defined deposits. Only one has been seriously developed, however. This property lies seven miles west of Empire. Peak 10 in the Ten Mile District, about eight miles north of Breckenridge, Summit County, has an eight-ft. vein of flaky molybdenite. A similar deposit is found at Peak 2, eight miles south of Breckenridge. In 1910 sixty tons of ore were shipped to Denver for treatment, but it was found too low-grade to handle. A large deposit is found in the San Juan. In this ore molybdenite is disseminated throughout a hard quartz in thin filmy seams. Near Silverton, however, flaky molybdenite associated with molybdite is found in several prospects.

Good ore which shows an average, in large samples of 2·5 per cent. molybdenum is reported in a large body near Monarch, Chaffee County. Molybdenite in quartz is found at Ophir.

Thirty miles northwest of Dillon, Mont., there is a 10-inch quartz vein carrying molybdenite. The country rock is granite.

Idaho reports molybdenite at Knob Hill, Kootenay County, and Utah reports wulfenite and molybdenite at Alta. Oregon has a non-producing deposit of molybdenite at Galice, Josephine County.

The molybdenum deposits of Canada are well reported by Dr. T. L. Waker, Canadian Bureau of Mines, 1911. They are as widely scattered as in the United States. The farthest west and one of the best is in the Nelson Mining Division, at Lost Creek, near Salmo in British Columbia. Much low-grade ore is reported in the dump. Several car-loads of higher grade ore were shipped to Denver in 1914 for experimental treatment.

There are several producing mines in the vicinity of Rossland, B. C., which produce some massive molybdenite with copper. Eighty-five tons of molybdenite ore, valued at $1275, obtained from 600 tons of rock, were shipped to the United States in 1908 from Sheffield, Addison County, Ontario.

In 1909 very promising deposits were described in Quebec, north of Ottawa, at Turnback Lake (Keewagama), in the Indian Peninsula. Veins are found which carry as high as 400 pounds molybdenite to the ton. The mineral is found at Gabarus, Cape Breton, Nova Scotia. Mont Cerf, Ottawa County, Quebec and Romaine on the North Shore of the Gulf of St. Lawrence, northeast of Anticosti Island are other promising localities. In 1902 a shipment of 6500 pounds of ore valued at $400 was made from Laxton township, Victoria.

From time to time small shipments of wulfenite have come from Mexico. Peru reports seven provinces in which molybdenum is found. New Zealand five localities. In Germany and Austria the Erzgebirge have produced a little molybdenum, but this as well as the production from other countries not described above, is comparatively insignificant.

MATALLURGICAL TREATMENT—CONCENTRATION.

The problem is not an easy one. Nearly everything has been tried of ore-dressing nature, on the molybdenum ores—no two of which are alike—and, on the whole with surprisingly interesting results. Molybdenite is different from most minerals. It is heavy like a metallic sulphide and behaves in part like these, and then it is flexible, and not brittle, with strong basal cleavage and a tendency to flake like graphite or mica. Ordinary methods of concentration are hardly applicable.

Complex ores, therefore, add to the metallurgist's troubles, and the physical condition of the molybdenite is another consideration.

By this is meant, (a) coarse flaky pieces or particles, (b) fine flaky particles or grains; both a and b; (c) thin flakes or filmy coverings.

The nature of the gangue material plays an important part, of course. A filmy molybdenite deposited in seams of a hard quartz is an extreme example of refractoriness. A coarse grained granite or pegmatite, carrying coarse mineral, is the other extreme.

When associating minerals, pyrite, chalcopyrite, bismuthite, native bismuth, chalcocite, their oxidation products or mica and pyroxene, or perhaps several of these are present in either of the cases above, the problem becomes complex.

However, combinations of newer principles such as flotation, magnetic and electrostatic separation, have done much to win good concentrates from ores which were looked upon quite unfavorably a few years ago. Only rarely does the mineral occur so coarsely divided that it may be hand-picked.

Yet this has been the case with the Australian deposits. At Kingsgate the mine of Mr. V. Sachs has yielded several lumps which weighed 85 lbs., 500 lbs. and 600 lbs., respectively. More than that, these lumps were nearly pure molybdenite. Hand cobbing was therefore a ready means of ore dressing and was used entirely in the early days of molybdenum's commercial history in Eastern Australia. Later the decreasing amount of such ore and the increasing low grade made mechanical treatment necessary.

In Queensland the dump from the tungsten mines was sorted for molybdenite by hand. Thus the major part of the Queensland production of 1909, amounting to 92 tons, valued at $46,360 was obtained in this way. However, there are now concentrating plants in Queensland and one at Sydney, N. S. W.

The ore dressing is described as follows:

The hand-picked rock is crushed in rolls and jigged. The oversize is crushed again, hand-picked and then treated on Wilfley tables. No data are available on saving and composition of concentrates. The impurities are bismuth, arsenic and copper. Mention is made of a payable mixed concentrate of molybdenite and bismuth, which was made for some years on vanners.

The Elmore process of oil flotation depends on the selective action of oil for sulphide particles. When oil particles attached to sulphide particles are agitated with water and air, bubbles are formed in and by the oil, which are then increased in levity by the action of a vacuum. Thus the sulphide particles are made to rise to the surface while the gangue remains on the bottom. The process is made continuous and a unit of apparatus can handle twenty-five tons of ore a day. The ore must be crushed to free the particles of molybdenite from gangue matter.

This method applied to East Australia ores gave the following results:

	1 Mo.	2 Mo.	3 Mo.
Original ore	2·61 per cent	3·07 per cent	51·21 per cent
Tails	·10 "	·06 "	·17 "
Concentrates ...	47·20 "	51·00 "	54·70 "
Extraction	96·2 "	98·1 "	97·00 "

Cencentrate I—78·66 per cent MoS_2 (molybdenite)
Concentrate III—91·16 " "

The gangue matter consisted of quartz, slate, mica and magnetite. It is to be observed that conditions of flaky molybdenite and absence of any other sulphides in the gangue were particularly favorable to this treatment.

In Norway the ore is partly hand-picked and partly concentrated on jigs and concentrating tables. The ore runs from one to three per cent. molybdenum sulphide. In many ores the filmy stringers make concentration difficult, but that which is found in bulk and which is easily mined may be successfully worked at one-half per cent. molybdenite contents. The Elmore process on 100 tons ground to 30 mesh gave a saving of 91·7 per cent. and the concentrates showed 84·8 per cent. molybdenite. The older method has been abandoned in favor of the Elmore process, at Flekkefjord.

In the United States the American Molybdenum Company, of Cooper, Washington County, Maine, attempted concentration by a process of coarse crushing and screening, thus depending on the flaky and tough nature of the molybdenite cleavage plate to outlast gangue matter in the process of crushing and rolling. That the idea was not rewarded may have been due to market conditions, but the principle lacks completion and the plant lacked mechanical efficiency.

The process is described as follows:

A 35-H.P. boiler and engine supplied the power. From a Sturtevant jaw crusher and rolls, 18-inch diameter by 4-inch width, the ore went to four special sets of rolls, each 3-ft. diameter and 10 inches wide with interspersed screening. In more detail, the crusher yielded ¼-inch ore to the Sturtevant rolls which yielded ⅛-inch product. From here the ore was elevated to a third special set of rolls, which dropped their product to a 34-mesh screen provided with a box to collect concentrates. The undersize was sent to a fourth special set of rolls and then through a 40-mesh screen which yielded a concentrate. The undersize was sent to a 60-inch screen and another concentrate formed. The tails were elevated to a dump pile. The operation seems to have been short lived.

Many earlier attempts at concentration undertook to use a straight crushing and screening separation, but no lasting result is recorded.

A treatment of a Canadian ore by J. Walker Wells, Kingston School of Mines, is described as follows:

The ore consisted of 50 per cent. pyrrhotite, 18 per cent. pyrite and 6·5 per cent. flaky molybdenite in a calcite matrix. The gangue matter was black mica, quartz and pyroxene.

Hand-picking the larger pieces of molybdenite followed division in a jaw crusher. The remainder was passed through rolls set 2 inches apart. Screens of 0·4-inch and 0·05-inch mesh were used successively. The coarse screen took 1·4 per cent. in flakes and the fine screen 1·54 per cent. The oversize from these, consisting of molybdenite, mica and vein rock, was put on a Wilfley table making a commercial product containing 55 per cent. MoS_2 and 45 per cent. mica. Treatment of this with a Wetherill magnetic separator worked well, but was considered too expensive. The result was a concentrate containing 90 to 91 per cent. MoS_2. The Elmore process was only partially successful because the larger particles of molybdenite refused to rise.

The ore at Turnback Lake (Keewagama), Quebec, has been successfully treated by Henry E. Wood, of Denver, doubtless by his flotation process, and Prof. J. C. Gwillim of the Kingston School of Mines. The Denver Engineering Works are said to have made a concentration of 25 into 1 with 100 per cent. recovery. The ore is described as containing bismuthite and mica.

A sample of 289 pounds ore containing 15·92 per cent. molybdenite from Egan County, north of Ottawa, Canada, gave a hand-picked product of 39 pounds. The remaining 250 pounds contained 2·8 per cent. molybdenite. This was removed by crushing in rolls, screening and jigging. The recovery was high but the concentrates ranged from 15 to 70 per cent. MoS_2. In this instance the associated minerals were pyroxene, pyrites and mica.

A Ross Township, northeast of Ontario, sample of 250 pounds, containing 1 per cent. MoS_2 gave a recovery of 55 per cent., but only a 33·5 per cent. product, which was too poor for commercial use.

Perhaps the most ingenious process and device for the concentration of molybdenite and similar minerals results from the study Mr. Henry E. Wood of this city has given the problem. In a sense it is unique. The process is a flotation without oil and depends upon the surface tension phenomenon, sometimes noticed in concentrating mills when particles of mineral float over the surface of water, under agitation even, without breaking through that curiously endowed film of surface water which is physically so unlike the water beneath it. The ore is added in form sufficiently fine to free the particles to be won and with sufficient care to prevent them from breaking through or becoming wetted. The gangue material breaks through and sinks. The surface film of concentrates is urged by a current of water toward a collector.

Briefly, the finely divided ore is distributed evenly and lightly over a rolling surface immersed partly in water contained in a hopper shaped tank. The surface concentrate film is formed and travels to a broad canvas belt which drags the concentrate off the surface and out of the water. The belt is cleansed by a wash spray and the concentrate pressed. The apparatus is light, cheap, compact and requires low power. Ores of clean quartz, which showed from 1 to 8 per cent. MoS_2 gave a concentrate with a contents of 80 to 90 per cent. molybdenite and a recovery of 80 to 90 per cent.

Other sulphides will also float off, but there are various ways of eliminating these, such as a light roast and subsequent magnetic separation of pyrite or chalcopyrite. Mica, if quite ferruginous, may also be removed by magnetic separation.

In view of some experiments conducted by Mr. W. G. Swart and by students at the Colorado School of Mines, the Blake-Morsher electrostatic separator suggests itself as an excellent means of separating flaky molybdenite from gangue, pyrite, chalcopyrite and mica, especially when the last is non-magnetic or very weakly so. The Huff type of electrostatic separator is recommended also.

Selective oxidation of sulphide minerals present suggests itself from a published experiment which is stated to have made a profitable separation from an ore carrying 3 per cent. molybdenite and considerable chalcopyrite. The flotation concentrate of both minerals was dampened and dried, thereby altering the chalcopyrite superficially. Upon subjecting this again to flotation the chalcopyrite sank.

Two theses published in the Colorado School of Mines are not without value in this problem. The one in 1904 concerns itself with a highly refractory ore from the San Juan region, Colorado. The ore was a hard quartz containing filmy microcrystalline stringers of molybdenite compactly enclosed. Pyrite was also present.

The conclusions were: Ground to 40, 80 and 100-mesh, concentration on a Wilfley table proved impracticable. Ground to 100-mesh and sifted on a still body of water, then drying the settlings and treating as before, a recovery of 32·6 per cent. of the molybdenum in a product running 20 per cent. MoS_2 could be made. Treatment by the Blake-Morscher process gave negative results. Flotation with oil was also not adapted to this ore. The above analysis of the original ore gave about 7·5 per cent. MoO_3 equal to 8·15 MoS_2.

The other thesis presented in 1911 was a study of treatment of Breckenridge ore of flaky kind, carry 5 per cent. MoO_3, equal to 5·61 MoS_2, with mica, pyrite and chalcopyrite present in considerable amount.

The conclusions were: Jigging, classification and table concentration were not applicable. The Elmore process gave high extraction, but a value too low in molybdenum to make a commercial product alone. A result of flotation with a Henry E. Wood concentrator, gave 87·6 per cent. extraction and 22·3 per cent MoS_2 in the concentrate. The mica proved amenable to separation by a Wetherill magnetic machine and the resulting product showed a total extraction of 82·2 per cent. with a contents of 55·8 per cent. MoS_2. Time prevented further experimentation aimed at the removal of the remaining impurities, pyrite and chalcoyprite. Perhaps a light roast followed by another magnetic treatment would have proved successful.

A unique method is disclosed in a Canadian patented process, in which the molybdenum is volatilized in a current of air at 800° C. and the oxide caught in bags.

GEOLOGY.

Molybdenum belongs to the acid forming elements. The oxide and sulphide are both of this nature. It is to be expected that magma separating from acidic rocks would form the natural deposits in which molybdenite is found. This would not take into account necessarily subsequent removal to other places of enrichment. Molybdenite is usually associated with igneous rocks or their metamorphic derivatives.

In the Australian deposits molybdenite is found at the junction of granite and the intruding rock, or near by. The former is of two kinds, coarse and fine grained. The latter may consist of porphyries, felsites, blue granite, andesites or slate. The contact with the last shows the most productive deposits.

The mineral may be present in scales scattered through the granite mass or in small quartz veins which forms are stated to be profitless; or it may occur in long, irregular segregations or "pipes" of quartz from 5 to 20 feet in diameter. In these the molybdenite may be associated with wolframite, tin and bismuth. The latter, as in the Kingsgate mines, have proved most productive. Reference has been made to lumps of mineral of great weight and high purity.

In Norway molybdenite ranging from 1 to 3 per cent. is found in joints and small quartz stringers in diorite and pegmatite zones. In places the ore is quarried where the mineral is scattered through granite, but in other places, underground workings cut the quartz veins.

In Maine at Cooper and Catherine Hill, the ore occurs in planes which intersect the granite along which, molybdenite, fluorspar and quarts have deposited. Over considerable areas, also, the granite is impregnated with flakes of molybdenite.

At Turnback Lake, Quebec, the mineral is found in quartz veins which are richest at the contact of coarse granite with schist, which the former intruded. Later intrusions of diabase are also noticeable. About 16,000 feet of these veins have been followed, some to the extent of 500 feet. At the northern end of the peninsula, about thirty or forty veins from 1 ft. to 10 ft. in width are shown with a general bearing northwest. Molybdenite is concentrated near the walls, leaving the middle portion of the vein barren. A rough concentration at the deposits is possible, therefore. About one-third the vein can be rejected and the remainder cobbed to one-half. A vein 8 feet wide averaged 6·4 per cent. MoS_2. Several others averaged 2·17 to 2·3 per cent. Fifteen scattered pits gave an average of 1·92 per cent. MoS_2.

Reduction of Concentrates.

Molybdenum is brought on the market in two forms, powder and ferro-alloy.

The first of these is invariably made by heating some form of oxide with a reducing agent. Carbon in form of charcoal is usually employed. The first stage of reduction is the dioxide which forms readily, and unlike the trioxide is not readily volatile. Prolonged heat and high temperature effect further reduction of this to metal.

The second form, ferro-molybdenum, with varying molybdenum contents, is made by use of the electric resistance-furnace, either direct from the sulphide or from the roasted high-grade sulphide. The advantage here is that impurities may be slagged off whereas in case of powdered metal, unless the impurities are subject to extraction with a solvent, they remain with the metal.

Before the increased present demand manufacturers were exacting. Standard requirements for concentrates were 85 to 90 per cent. MoS_2 and except in very small amounts, copper bismuth, arsenic and tungsten, when present, were penalized. Because of increased demand the requirements are made more easy to meet.

The reasons are obvious. The purer the molybdenite, the less treatment required for the final operation of reduction. When the demand is greater than production, as at present, the increase in price takes good care of additional preliminary refining treatment of lower grade material. The preparation of the oxide in commercially pure form is not an easy matter.

This may be done by roasting the sulphide first to oxide and then leaching the mass with ammonium hydroxide, which dissolves the oxide to form ammonium molybdate. Copper oxide forms an objectionable constituent because it also dissolves and reappears in the subsequent evaporation of the ammoniacal solution. Evaporated to crystallization, preferably under reduced pressure, so-called ammonium molybdate crystallizes out from the filtered solution. This contains 81·55 per cent. of molybdic oxide, 8·27 per cent. ammonia and 10·19 per cent. water. On ignition ammonia is driven off and molybdic oxide results. A previously mentioned process whereby the oxide is won by volatilization directly from the ore, may be referred to here.

When the oxide is heated in a wind furnace with carbon in graphite crucibles a dark powder results which is commercial molybdenum. An analysis of such a product showed 95 per cent. molybdenum and 2 to 3 per cent carbon combined by cementation. The metal forms carbide readily. With care a product may be made 99 per cent. pure.

Among the early manufacturers Sternberg and Deutsch in 1892 made a metal which contained 3 per cent carbon by igniting precipitated calcium molybdate, in similar fashion, with carbon. Their factory was situated near Berlin and the capacity was 200 Kg metal a day. The admixed calcium oxide was leached out of the metal with hydrochloric acid. The metal at that time brought 86½ cents a pound. It contained 3 per cent carbon.

Moissan first introduced the use of the electric furnace. By heating ammonium molybdate he made the dioxide which he treated with 10 per cent pure carbon. The resulting metal contained carbide.

Guichard produced a metal of high carbon contents directly from the sulphide in the electric furnace. The ore, nearly pure molybdenite, gave a metal of 91·5 per cent. molybdenum, contents. Current used, 300 amp. 50 V.

Robert Keeney of the Colorado School of Mines, found that either the raw or roasted ore can be used in making ferro-molybdenum in the electric furnace. Lime is used as a fluxing and desulphurizing agent. Ferric oxide is subsequently added for decarbonizing purposes. In the case of direct use of molybdenite the sulphur slags off in form of calcium sulphide. With a current of 900 amp. 50 V. sulphur is found to be entirely expelled from molybdenite. However, about 7 per cent. of carbon is absorbed, partly graphite. This can be reduced by the decarbonizing action of freshly added oxide. Wulfenite when fluxed with sodium carbonate gives oxide of lead and sodium molybdate. The latter is soluble in water; the former is not. From solution the oxide can be gotten and worked into metal. Such mention seems necessary now since wulfenite in 1914 found a good market at 60c per pound of MoO_3 contained in good grade concentrate.

The thermit or alumino-thermic process, which depends upon the greater heat of formation of aluminium oxide for reduction, produces a high-grade metal free from carbon. Ninety-eight to ninety-nine per cent. of molybdenum and the remainder iron is the composition of the product.

USES.

Molybdenum is used in form of oxides, ammonium salt and metal. Several tons a year are used in the United States in form of ammonium molybdate as laboratory reagent in the determination of prosphorus in iron ores, their products and in fertilizers. The salt finds a further use in fire-proofing fabric. The metal is used in self-hardening steel. From 5 to 10 per cent. is introduced and the resulting steel is raised in elastic limit and tensile strength, and possesses greater toughness in addition to the former property. Wire made from it is said to have greater elongation and high tensile strength.

Other uses are in large castings; gun barrels in which it is prized for its resistance to corrosive gas action; armor plate; armor piercing shells; (the last two uses contradicted in U. S.) motor-car steel; magnets.

Equal parts of molybdenum and chromium introduced into steel are proclaimed preferable for many of the above uses, especially self-hardening steel. Two to five per cent. of molybdenum and 10 per cent. chromium with little or no carbon are said to make steel acid-resisting to a great degree. Nickel-molybdenum ferro alloys also find use. The tensils strength of molybdenum wire is given at 200,000-270,000lb. per sq. in. as compared to tungsten with 480,000-580,000 lbs. per sq. in.

Molybdenum-wire electric furnaces have special claims made for them. A thermo-couple which uses the metal has been described recently. The lower oxides of molybdenum are highly colored. Their use is recorded in coloring leather, rubber and porcelain. A soluble variety is used as a substitute for indigo.

In some form it is added as a preservative to certain smokeless powders.

MARKET, OUTPUT, STATISTICS.

Prior to 1900 little use was made of the metal. From 1900 to 1905 a gradual increase in the production of molybdenum metal took place. Then there was a decline until the opening of the present war, when demand increased rapidly with rising price and today astonishing figures record market advance.

Not long ago a prominent engineering journal scoffed at the alleged importance of molybdenum, but recently the same journal published an appeal from the Imperial Engineering Institute of England to Canadian producers of molybdenum ore. This is the history of the rare metals. Their growing utility cannot be denied. It must be remembered that all useful metals had their modest industrial beginnings.

It has been stated frequently that dull markets were due to uncertain output. This may have been so before modern concentration methods were used, but this reason is no longer valid. When consumers consent to pay the price which makes the mining and concentrating enterprise worth while, the supply will prove adequate to the demand.

The Australian output in..........	1902	was	15	tons	valued	at	£ 1841
	1903	"	29	"	"	"	4450
	1904	"	25	"	"	"	2726
The New South Wales output in..	1911	"	20·65	"	"	"	2591
	1912	"	56·5	"	"	"	3706
	1913	"	73	"	"	"	6400
	1914	"	61	"			
The Queensland output in........	1911	"	99·5	"	"	"	13279
	1912	"	102·3	"	"	"	17349
	1913	"	57	"	"	"	16185

In 1915 Australian ores rose to $28.00 a unit.

Not counting the small annual production of Norway and scattering parcels, the above figures represent most of the best years of molybdenum production.

There is little doubt that 1915 and 1916 will show astonishing figures, record output and prices, together with considerable development in hitherto neglected fields.

It is not safe to predict a continuation of these, however, for an indefinite period. Substantial prosperity in rare metals has been marked by a slower growth.

VANADIUM.

Historical.

The element was first identified with certainty as a new element as late as 1830 by the Swedish chemist Sefstrom who found it in the iron from the ore of Taberg. He named it vanadium from Vanadis the name of Scandinavian Goddess Freyja, the Earth Mother.

In 1801, twenty-nine years earlier, Andres Manuel Del Rio, professor of minerology, Royal School of Mines, City of Mexico, thought he had discovered a new element in some samples of lead ore which he had obtained from Zimipan, Mexico. He named it erythronium because acids formed red compounds with it but decided later that he was working with an impure chromium compound. In this reversal of opinion in 1804 he was influenced by the French chemist Collet Descotils, who combatted Del Rio's claims. Wöhler in 1830 proved the correctness of Del Rio's first supposition and barely missed the honor of anticipating Sefstrom. In his letters to Liebig he bewails the result of his procrastination. Berzelius followed in 1831 with a published study of the impure metal and some of its compounds which fixed an opinion that the element was an analogue of chromium.

In 1867 the classic work of Sir Henry Roscoe disturbed this belief. A study of the oxygen derivatives by him, especially, showed a closer resemblance to the nitrogen group. Roscoe also obtained the metal in pure form for the first time by reduction of the dichloride in pure hydrogen. He showed the metal of Berzelius to be the nitride.

Commercially vanadium did not rise to great importance until about a decade ago. It is true that in a small way there has been a market for a longer period. It has found limited use in calico printing. In conjunction with chlorate of potash it converts aniline into aniline black. It produces a permanent black on leather which has been tanned with gall nuts and may also be made into ink with gallic acid. Vanadium salts are sometimes used in coloring glass and porcelain. As a catalyst it forms the basis of a patent for making sulphuric acid. But not until a study was made of its effect upon steel did the vanadium industry rise to its present importance. Since about 1904 the importance of this has been felt in the search for deposits and methods of concentration and reduction, the effects of which have been the growth of a new industry in the United States and the discovery of large deposits in Peru and Colorado. The first shipments of uranium concentrates made in 1900-1901 from the carnotite mill of Messrs. Poulot and Voilleque on the Dolores River at McIntyre, contained as high as 12·5 per cent. vanadium oxide which brought no return. Exception was made in one or two instances when the vanadium oxide contents were paid for at the rate of twenty-five cents a pound for that contained. Before ten years had elapsed the price of this oxide reached two dollars a pound and the metal sold at five dollars per pound contained in the alloy ferrovanadium. Later the price declined to two and one-half dollars a pound for vanadium metal contained and lower prices than this have been recorded. These facts mark the natural stride of a rare metal into the commercial class.

PHYSICAL AND CHEMICAL PROPERTIES.

The purest metallic vanadium is micro-crystalline, silvery-gray in color and hard. Its specific gravity is 5.688, and melting point 1715° C. The metal prepared by Muthman of Munich shows vanadium to be the hardest metal known, since it scratches corundum. It is insoluble in hydrochloric acid. Hot and cold solutions of alkalies have no effect but fused alkalies dissolve it. It is stable in air at ordinary temperature but in finely divided form it is oxidized when heated in air. Chlorine attacks it at ordinary temperature and forms the tetrachloride which volatilizes when heated. It forms several oxides of which the pentoxide V_2O_5 is the most important. The latter dissolves in alkalies forming vanadates and in acids forming corresponding salts of oxygenated vanadium radicals. It combines with nitrogen at high temperatures to form a mononitride VN. A delicate test for all soluble vanadium compounds is to add hydrogen peroxide to a solution acidified with nitric acid. A cherry-red to blood-red color ensues.

MINERALS AND ORES.

The principal minerals given in the order of their technical importance are:

Patronite. An impure trisulphide of vanadium.
Specific gravity: 2·67-2·71.
Hardness: 2·5.
Color: greenish black.
Fracture: uneven.
An analysis of this ore is:

Sulphur soluble in carbon disulphide.....	4·50	per	cent
Sulphur combined	54·29	“	“
Vanadium	19·53	“	“
Water at 105° C.......................	1·90	“	“
Silica, SiO_2	6·88	“	“
Nickel	1·87	“	“
Iron, titanium oxide, alumina, phosphoric acid, manganese and chromium oxide, difference about	10·00	“	“

In purer samples the vanadium reaches 24·8 per cent.

Roscoelite. A vanadiferous mica, commercially found intermingled with sand grains in sandstone.

Analysis of this ore, high-grade, is:

Vanadium trioxide, V_2O_3..................	12·84	per	cent
Alumina, Al_2O_3	22·55	“	“
Silica, SiO_2	46·06	“	“
Potassium oxide, K_2O....................	8·84	“	“
Water, combined and uncombined........	6·05	“	“
Ferric oxide, calcium oxide, barium oxide, magnesium oxide, sodium oxide......	3·66	“	“

The mineral roscoelite occurs in thin scales arranged in fan shaped groups. Color, dark brownish green. Soft, S.G. 2·902. Contains 28·6 per cent. vanadic oxide V_2O_5.

Carnotite. A hydrous potassium uranyl vanadate.

An analysis is:

Uranium oxide, UO_3	64·70	per cent
Potassium oxide, K_2O	10·97	" "
Vanadium pentoxide, V_2O_5	20·31	" "
Ferric oxide, Fe_2O_3	·96	" "
Water, H_2O	5·15	" "

Other ores, containing dark-green and black vanadium minerals such as Kentsmithite, are included in the roscoelite group of ores.

Soft, waxlike or powder.

Color: canary-yellow to reddish-yellow.

The mineral usually occurs as a loose powdery encrustation on sand grains in sandstone or shale; sometimes colored green or bluish green by copper compounds; usually admixed with other uranium and vanadium compounds. The uranium oxide contents vary from one-half per cent. to eight and ten per cent. in ores.

Vanadinite. Lead chloro-vanadate.

An analysis is:

Lead oxide, PbO	78·70	per cent
Vanadic oxide, V_2O_5	19·36	" "
Chlorine	2·50	" "

Form: prismatic.

Specific gravity: 6·66-7·23.

Hardness: 2·75-3.

Color: brownish-yellow; straw-yellow; red-brown.

Subtranslucent, opaque.

Fracture: uneven.

Brittle.

Descloizite. Lead pyrovanadate containing lead oxide 70·9 per cent., vanadium pentoxide 29·1 per cent.

Other sources of vanadium are vanadiferous mimetite (lead chloro-arseniate) ; coal ash ; volborthite ; (hydrous copper vanadate), and some iron ores from which it finds its way into iron slags.

OCCURRENCE AND GEOLOGY.

Deposits of vanadium, said to be the most important in the world, lie in Peru. They are situated on the eastern slope of the Andes Mountains in the Department of Junin. The more important, in which is found patronite, lie in the Province of Pasco, district of Quisque or Minasragra. The less important, containing vanadiferous asphaltite, lie in the Province of Tarma in the Yauli district to the south of the former. They are within 80 miles of the Pacific Ocean. The Cerro de Pasco R.R. penetrates the latter district but the former lies about 30 miles west over mountain road from the nearest railroad point.

Historically, vanadium was known to be present in the asphaltite of the Yauli district as early as 1892. French owners of silver mines there acquired some of these deposits and are said to have shipped to France some tons of vanadiferous ash. Work ceased in 1899. An area of 5 by 12 miles embraces these deposits. Geologically they occur parallel to the contact between the jura-trias conglomerates and sandstones and the cretaceous shales and limestones. The asphaltite is found in lenses up to 22 ft. in width and as long as 500 ft., often separated by thin layers of shale. The mineral is black, lustrous and softer than bituminous coal from which it differs in other respects. The amount of ash is quite variable between the limits of 1·24 per cent. and 46·9 per cent. The vanadic oxide in the ore varies from 0·64 per cent. to 1·4 per cent. That in the ash will differ widely therefore, from 2·3 per cent. to 77·5 per cent.

The importance of the second district was brought to the attention of Senor Antenor Rizo Patron, metallurgist at the Huaraucaca Smelter in 1905 by some Indians who were prospecting for coal. The large quantity of sulphur in this material had previously condemned its use for coal. Its occurrence had been noted near Quisque whence, indeed, these men had brought it.

The formations are like those of the Yauli district and the vanadium is found within the red shales in veins conforming in direction to the mountain axis. Intrusions of dykes and laccoliths are indications of considerable igneous activity. The volcanic intrusions are trachyte, dolorite, andesite quartz porphyry and diabase.

The lens containing the vanadium has a maximum width of 28 ft. and length of 350 ft.; a strike N. 20° W. and a dip 75° W. It is composed of three substances, namely: Quisqueite, a hydrocarbon; coke containing globules of the latter, and patronite which has been described above. In addition much of the surrounding shale is impregnated with vanadium and this adds to the commercial value of the deposit.

The roscoelite deposits of Southwestern Colorado are best seen in and about Placerville.

Placerville Deposits.

Placerville is on the Rio Grande Southern Railroad, at the junction of Leopard Creek with the San Miguel River, in San Miguel County, Colorado. It is twenty-six miles by rail from Ridgway and eighteen from Telluride.

The country about is level or mesa land, about nine thousand feet above sea-level, through which the rivers have cut canons nearly two thousand feet deep and a mile or so in width. The exposures along these canons show that the mesas are made up of extensive, nearly horizontal, sedimentary beds, consisting, near Placerville, of red sandstones and conglomerates of triassic age, which extend from the bottom of the canon to a point nearly one thousand feet above. This is called the Dolores formation. Above it lies the La Plata formation, which consists of two beds of white sandstone, separated by a thin stratum of black limestone. Above this is the McElmo formation, consisting of light-colored sandstones and shales. It reaches to the mesas above.

In the lower part of the La Plata beds, at a distance below the limestone varying from nothing to twenty feet, there occurs in places a dark green strip or impregnated zone, the color of which is due to the vanadium mineral roscoelite.

Important groups of claims are found on both sides of Leopard Creek about two miles from the station, the group on the east side continuing interruptedly to a considerable distance past Placerville along the north side of the San Miguel to Sawpit. Other groups are found on Fall Creek; and the claims in Big Bear Creek, about two miles from Newmire (now called Vanadium) have been consistently mined by the Primos Chemical Company for the refinery at the railroad.

The ore, varying in color from sage-green to olive, is found in irregular bodies along the bedding planes above mentioned. The bodies vary much in thickness, sometimes reaching 6, 8 and 10 feet and may be of considerable length.

Carnotite occurs in a broad expanse of land in the southwestern and western counties of Colorado and eastern Utah in the jura-trias sandstones. It forms impregnations in the latter, deposited on the grains and often admixed with shales of bituminous nature. Much fossil wood sometimes richly impregnated with carnotite has been observed. Since the extraction of vanadium is always incidental to the extraction of radium and uranium, these localities of occurrence may be more properly described when considering these metals.

Frequently vanadinite has been a source of vanadium in the past decade. Much of the vanadium which has been worked in Germany has come from vanadinite ores or concentrates obtained from Spain and Mexico. Grand County, New Mexico, has furnished such ore and so has Arizona.

The vanadinite ores from Estramadura, Spain, show from 11·49 to 13·5 per cent. vanadium pentoxide. That from the vanadiferous dumps at Georgetown, Grand County, New Mexico, contains 7·5 per cent. vanadium metal equivalent to 13·4 per cent. vanadium pentoxide. The Cutter deposits of New Mexico lie in the Caballo Mts., north of Polomas Pass. Concentrates run 8·63 per cent. vanadium equivalent to 15·3 per cent. pentoxide.

Mexico ore has been shipped from Chihuahua. Vanadinite concentrates from Cochise County near Dragoon have found sale at times. The only instance known to the author in which descloizite forms the raw material came through samples of ore from Ecuador, and a fine ingot of fused vanadium pentoxide made from this ore at the factory of M. Bonnemaison, near Paris.

Recently, splendid samples, probably mottramite, were received from a former graduate of the Colorado School of Mines. They are said to have been taken from a huge deposit near Cold Springs, Nevada.

Quite interesting, but undeveloped, is a deposit of volborthite, hydrous vanadate of copper, which occurs at Garo, Park County, Colorado. The jura-triassic sandstone exposed one-half mile south of the C. & S. Station is stained a siskin green and is said to have been found in quantity. Analyses ranging from 5·5 to 8 per cent. copper and 0·55 to 2 per cent. vanadium oxide are recorded.

Numerous other localities of the metal are known but under present conditions they do not excite interest.

METALLURGICAL TREATMENT.

CONCENTRATION AND REFINING.

Except in the case of the lead minerals there is not much opportunity for concentration as ordinarily understood. Both vanadinite and descloizite may be concentrated over tables, the crystalline nature and the high gravity which the lead gives them making this possible. Ores running from one to two per cent. of the mineral may be concentrated to run 14 and 15 per cent. of vanadium pentoxide and since the pure mineral assays 19·36 per cent. pentoxide a concentration of about 35 into 1 is possible on an ore containing two per cent. vanadinite.

A kind of concentration is produced in the Peruvian field by burning off the free sulphur and at the same time roasting the vanadium sulphide to pentoxide. Patronite ore treated this way loses about 45 per cent. weight.

An analysis of such calcine is:

Vanadium pentoxide	58·08	per cent
Iron oxide	4·98	" "
Molybdic oxide	2·62	" "
Nickel oxide	2·24	" "
Silica	25·00	" "
Sulphur	0·23	" "
Lime, magnesia, potash, soda, etc.	Diff.	

This feature is valuable when it is considered that the ore must be transported to the railroad on the backs of the llama, an animal which can carry a load of about 50 pounds only. Furthermore, the ore is sent a great distance, to Pittsburgh, Pa., for refinement, and this necessitates long haulage and considerable handling all of which profit by the above simple concentration.

In the case of roscoelite concentration is impossible and direct treatment of ore at the refinery is necessary. Carnotite is concentrated both by mechanical and chemical means near the mines but much of it has gone directly from the mines to the refiner. Only mention need be made here of the means employed since they will be described later on.

Air-blast concentration of the particles of carnotite released from the ore by grinding has been a principle on which two plants have been built.

Water elutriation has been used in a small way.

Concentration at or near the deposit by chemical means, which involves use of alkalies and acids, has been employed successfully, but this has a disadvantage over the less complicated mechanical means from which, nevertheless, there may be no final escape because with the latter it appears to be impossible to remove much more than half the carnotite from the sand grains economically. Then there are certain other advantages of a straight or a mixed chemical treatment which will be described under uranium.

Air or water concentration produces a concentrate containing carnotite powder admixed with clay, calcium carbonate, shale or whatever else may have been contained in the ore, and in some cases this runs very high but in the average will run between 10 and 20 per cent. of the ore on low-grade ores. It may be said here that the tailings are in much better condition for chemical treatment than before. The vanadium in such concentrates has a varying percentage but may run several per cent. in a concentrate obtained from an ore containing one per cent. uranium oxide.

From an alkaline leach the vanadium is obtained as an impure calcium vanadate of low vanadium contents.

From acid-leach method the vanadium is obtained mainly as a green ferrous vanadate admixed with uranium compounds and gypsum, provided limestone is used as precipitating agent. A technical run on considerably more than 100 tons of low-grade ore (about 1 per cent. uranium oxide and 1·3 per cent. vanadium oxide) averaged 10 per cent. vanadium pentoxide.

The refining stage, as distinct from the concentration stage, aims to prepare the concentrate for the ferro-alloy which is afterward to be introduced into steel. The forms are usually two in number, namely: Vanadium-pentoxide and ferrous vanadate.

The first of these is a red body obtained by ignition of hydrated vanadium oxides or from the salts of vanadium which are decomposed by heat.

Vanadic oxide fuses at 500° and solidifies to a crystalline mass.

Ferrous vanadate is a green to gray-green flocculent precipitate which dries to a yellow-brown mass.

Roasted patronite and allied ores are amenable to several forms of treatment; but a simple one in point of theory, and it is stated to be simple also in practice, consists of leaching the raw product in lead-lined pots with sulphuric acid, decantation and clarification of the liquor, evaporation of the liquor in lead-lined vessels to suitable concentration and subsequent ignition of the residual product to vanadium pentoxide. The product is ready for reduction to ferro-alloy.

Roscoelite is worked up into ferrous vanadate by the following process on an ore which contains about two per cent.

vanadium. The ore is crushed to 2-in. size and put through a drier after which 2·5 per cent. of iron sulphide and 8 per cent. salt are added. A Krupp ball-mill discharges 18-mesh material to conveyors which carry the material to an Edwards-McDougall furnace where the ore is roasted at from 700° to 1200°. The salt-roasted ore is sent by belt conveyor to vats into which it is discharged through launders by a circulating solution. The latter is partly cooled and precipitated with ferrous sulphate solution. The product carries about 30 per cent. vanadium and is directly reducible in the electric furnace. This is essentially the process introduced by the Vanadium Alloys Co., in Newmire, in the plant now operated by the Primos Chemical Co.

A similar product is obtained when carnotite is leached with sulphuric acid and precipitated with limestone. The greenish precipitate so obtained contains ferrous vanadate which when dried turns yellow. It carries 10 to 12 per cent. vanadium pentoxide. When this precipitate is treated with sulphuric acid and heated, the uranium and vanadium go into solution. Sodium carbonate added to excess precipitates aluminium and iron. In the filtrate caustic soda brings down the uranium as sodium uranate containing some vanadium; and the filtrate from this, when neutralized, is precipitated with ferrous sulphate.

In the recent publication on radium by the Bureau of Mines this well known process is employed in a solution of nitrates and a similar precipitate is made.

The Bleecker process proposes an alkaline extraction of the ore and subsequent precipitation of the vanadium as copper vanadate. This is collected, fused, cast into electrodes and electrolyzed.

The process formerly employed at Cutter, N. M., for the reduction of vanadinite is similar to that used for patronite. The finely ground ore is admixed with concentrated sulphuric acid and after decomposition has taken place, the mass is leached, the lead sulphate separated for smelter use and the vanadium liquor evaporated to proper consistency for final ignition to oxide.

Another method said to be in favor abroad is to heat the finely ground ore with soda ash in a reverberatory hearth. The oxide of lead forms a regulus and the soda slag contains the vanadium which is leached, evaporated and treated with strong nitric acid to liberate the vanadic acid which is collected, washed and fused to the pentoxide. Iron slags containing as high as 2 per cent. vanadium form a source of supply. Methods have been described for the recovery of vanadium from the slags of the Cruesot Steel Works and from the Taberg slags.

Further treatment from now on is for the purpose of reducing these compounds to the metal for introduction into the steel bath.

In general the electric furnace is used but the aluminothermic process or a modification of it is also employed. Recently a publication advances the hope that this many-stage process from ore to steel will be reduced by one and that is the reduction to metal, under consideration here. Considerable losses, partly mechanical and partly chemical are encountered in this stage and now the proposal is made to prevent this by adding the vanadium compounds together with iron scale and a reducing agent such as silicon directly to the steel in molten condition. The suggestion is backed by interesting and promising experiments.

Moissan in his classic experiments with the electric furnace opened the way to reduction of many a metal oxide to metal heretofore considered a curiosity. Vanadium oxide was one of these. Moissan's vanadium was not pure, however, but contained much carbon. To lessen the carbon contents many expedients have been employed such as a partial reduction with carbon whereby carbides do not form, and then completing the reduction with aluminium or silicon. Calcium carbide and carborundum have also been proposed as reducing agents. Nevertheless, in spite of the statements, frequently encountered, that indirect reductions in the electric furnace are the most satisfactory, ferro-vanadium has been prepared with low carbon contents as is shown by the following analysis:

Vanadium	25·65
Carbon	·75
Silicon	·44
Sulphur	·044
Phosphorus	·067

It is known that ferrous vanadate has an advantage over vanadium pentoxide in that its fusibility and volatility lie very high. Vanadium pentoxide melts at 500° C. and allows pellets of the oxide to form which then admix mechanically with the alloy formed or the slag. On the other hand an alloy of higher vanadium contents is formed. To prepare the metal itself a preliminary treatment of the pentoxide has been proposed which overcomes the above difficulty. In this treatment the pentoxide is first reduced with a specially prepared vanadium carbide to the trioxide and this is then used in the fusion. The trioxide has a fusing point of 2000°C. which is well above the melting point of vanadium. Using carbon as a reducing agent in the furnace a yield of 57 per cent. as against a theoretical yield of 60·8 per cent. is shown. This is considered good. The reaction takes place smoothly and speedily and an analysis gave 98·1 per cent. vanadium and 1·9 per cent. carbon.

USES OF VANADIUM.

It has already been stated that vanadium imparts certain valuable properties to steel and under the description of its uses these properties may well be considered.

In this country J. Kent Smith, and abroad Captain Nicolardot and Leon Guillet have been pioneers in the study of these properties imparted to steel.

The first gentleman ascribes the action of vanadium to both physical and chemical causes. He states that the affinity of vanadium for both oxygen and nitrogen excludes these two steel poisons up to the last traces. These products are then eliminated in the slag, no danger of dryness resulting therefrom. Furthermore, metallographic studies of vanadium steel reveal the fact that the ferrite forms a solid solution with the vanadium thereby causing the ferrite to become much tougher through greater interlocking of its crystals. The ferrite crystals are made stronger from a tensile-strength stand point. Vanadium ferrite resists the passage of carbides through it more than does ferrite itself. Two effects follow, viz.: Greater tempering benefits to the steel and wider tempering limits. These facts are in contradistinction to carbon steel of the subsaturated kind, i. e., those which contain less than 0.89 per cent. carbon.

The pearlite alloy is affected in two ways: Its elastic limit is raised and its cohesive ability with ferrite is promoted. It has been found that a prominent property of steel cannot be gauged by static test. This property is the fatigue phenomenon or resistance to shock. Of all properties of vanadium steel this stands out most prominently. It is very remarkable that addition of 0·15 per cent. to 0·25 per cent. of vanadium in the steel is usually sufficient to bring about these changes. Numerous published tables which contrast vanadium steel, vanadium-chromium steel, vanadium-carbon steel and others containing vanadium, with straight carbon and other carbon alloy steels show superiority in static factors, and special methods devised to test fatigue show much greater superiority.

With regard to this peculiar ability to resist fatigue the following comparisons are eloquent:

A structural steel of high quality, a high-grade structural nickel steel (Sheffield) and a vanadium steel were submitted to a destructive shock with the following results:

Carbon steel	11	foot pounds
Nickel steel	14	“ “
Vanadium steel	17	“ “

With repeated less violent shock blows:

Carbon steel stood	25	blows
Nickel steel stood	35	“
Vanadium steel stood	69	“

With repeated lighter impacts:

Carbon steel stood	300	blows
Nickel steel stood	290	“
Vanadium steel stood	540	“

Still lighter impact:

Carbon steel stood	900	blows
Nickel steel stood	800	“
Vanadium steel stood	2700	“

Still lighter impact, alternations of stress increased to 1200 a minute:

Carbon steel stood	6000
Nickel steel stood	10000
Vanadium steel stood	67000

A sample of vanadium steel was tested on a vibratory stress machine. Several samples of carbon steel all broke after 20,000 revolutions. The vanadium steel endured 100,000,000 and remained unbroken.

Allied tests such as bending, torsion and spring showed consistently superior results over older types of steel. The relationship of vanadium to shock resistance established, the benefits imparted to crank shafts, springs, etc., become evident. Applications are axles, connecting rods, piston rods, crank shafts, crank pins, gears in constant mesh, hammer rods, bolt steel, solid wheels, gun barrels, spring carriage, automobile, locomotive, case-hardening steel.

Further uses, in addition to those already mentioned, are as copper-vanadium and aluminium-vanadium which contains 3-5 per cent. vanadium.

STATISTICS.

The beneficial qualities given steel by vanadium are those which made a reputation for Swedish mild iron. This knowledge was enhanced much through experimental evidence even before any single large deposit of vanadium was discovered. In 1904 persistent rumors of the wonder-working qualities of vanadium were about, but it was not until production from large recently discovered deposits became a fact, that vanadium steel began to appear in quantity in the market. Earlier prices for vanadium in ferro-vanadium ranged about five dollars a pound for the contained metal. Later this dropped to four dollars and then to three-fifty and three dollars a pound in 1911. The present price is two dollars. From two dollars a pound for the vanadium in high-grade concentrates the price has dropped to between eighty-five cents and one dollar. Low-grade concentrates bring from thirty to thirty-five cents a pound. In 1907 the output value was only $27,330. From June, 1906, to Jan., 1909, Peru shipped to the United States 1800 tons of oxidized ore carrying 25 per cent. vanadium oxide and also the calcine from 400 tons patronite. In 1911 the Minasragra region output amounted to between 200 and 400 tons of calcine containing 25 per cent vanadium. For the same year the Vanadium Sales Co. reported distribution of 700,000 lbs. ferro-vanadium alloy to 57 plants in the United States and Canada.

The shipments from Colorado have embraced high-grade ore, ferrous vanadate from the Newmire Mill, carnotite ores high and low-grade, carnotite concentrates from mechanical and chemical processes, and recently, ferrous vanadate from the government plant.

The years 1910 and 1911 were particularly active, seventy-three carloads of ore and concentrate having been sent from southwest Colorado. Some of the past and present producers in Colorado are summed up in the following list:

The Rare Metals Mining & Mfg. Co. (Poulot & Voilleque).
The Western Refining Co.
The Dolores Refining Co.
The Vanadium Alloys Co.
The International Vanadium Co.
The Standard Chemical Co.
The Primos Chemical Co.
The National Radium Institute.

In addition to these may be mentioned the Vanadium Mines Company, Cutter, New Mexico, not now in operation, and the American Vanadium Co., of Pittsburgh, largest refiners and operators also of the Peruvian deposits.

URANIUM.

HISTORICAL.

Uranium has had a longer use, although limited, than any other rare metal. Unlike molybdenum, tungsten and vanadium it has not been brought into the public eye by any newly discovered virtue. It has had its place, nevertheless, in commerce to the full extent of its production, mainly in form of salts, until recently, when with the discovery of radium it was made less obscure in the more or less reflected publicity given it by radium, with which uranium is intimately associated.

Klaproth discovered it in pitchblende, the natural oxide, and autunite, calcium-urano-phosphate, in 1789, and gave it the name uranium in commemoration of the discovery of the planet Uranus by Herschel in 1781.

Martin Heinrich Klaproth deserves mention at this point, not alone for the discovery of uranium but also of zirconium and titanium, the result of a keen conception of methods for exact mineral analysis so wonderfully enchanced during the time of Berzelius. Klaproth was born in Wernigerode, Braunschweig, Prussia in 1743. He was an apothecary until 1787, when with the founding of the University of Berlin, he became its first Professor of Chemistry and remained in this chair until his death in 1817.

The metal was supposed to have been isolated by Klaproth but the material gotten by his process of reduction of the calx was recognized to be a lower oxide by Peligot, who in 1840 for the first time prepared the metal by fusing 75 grams of uranium tetra-chloride, 150 grams potassium chloride and 50 grams sodium. The product was found to be a hard malleable and light colored metal of specific gravity 18·33.

The names of many prominent earlier chemists, notably Berzelius and Arfvedson, are linked with processes for obtaining uranium salts from its ores, principally uraninite or pitchblende. The history of uranium ores is almost entirely one of this mineral which for nearly a century has been produced in the Erzgebirge of Bohemia at Joachimsthal, Bohemia, and Johanngeorgenstadt, Saxony. The discovery and exploitation of American pitchblende deposits, principally Quartz Hill, in Gilpin County, Colorado, are quite recent. Joachimsthal, situated near the Saxon frontier, 10 miles north of Carlsbad, is a very old mining town. Silver mining and the coining of the Joachimsthaler, began in 1518. The manufacture of uranium compounds from pitchblende found there, dates back beyond statistical record. The greater part of the world's uranium supply came from here in the latter years of the nineteenth century and the early years of the twentieth. With the discovery of radium the waste heaps from the uranium recovery process became of value and were carefully conserved. The Przibram lead mines also contain small amounts of pitchblende. The lead and silver mines of Bohemia were formerly of private ownership but became indebted to the Austrian Government to such an extent for loans that the government finally took control.

The closing of the Austrian mines in 1899 gave a stimulus to American pitchblende and carnotite production which increased with the discovery of radium.

A smaller output of uranium, but a steady one has been made from the ancient mines of Johanngeorgenstadt, in Saxony, south of Annaberg. The town was founded in 1654 by Protestants who were driven out of Bohemia.

The United Kingdom has produced pitchblende for many years principally in Cornwall. In 1912 an organization headed by Sir William Ramsey took over the mining of Cornish pitchblende here for the purpose of obtaining the radium. Pitchblende in America has been known in importance since 1871, when Dr. Richard Pearce discovered it in the Wood Mine, Central City. Three tons were shipped to London yielding a return of $7,500. A paper was read before this society Sept. 9, 1895, by Dr. Pearce on Colorado pitchblende. In 1894 the mine was reopened and the shaft lowered. A lens of pitchblende was found.

The accumulation of a number of years was shipped to France in 1899 when the Austrian supply was cut off. Since then the Wood, Kirk, Alps, German, Belcher and Calhoun Mines have produced intermittently and have shipped a number of tons of high-grade ore and a considerable quantity of low-grade.

Portugal began the mining of uranium ores in 1908 in the provinces of Minho and Beira. One company employed 600 men. The ores are autunite and chalcolite.

In 1912 there was organized the Radium Extraction Co., with mines near Olary, South Australia. The company has been operating under the patents of Prof. Sidney Radcliff, Director of the School of Mines of Bairnsdale, Victoria, S. Australia. The ore is carnotite associated with titanium and other rare-earth minerals.

Many "old timers" seem to have known of the yellow ore in the McIntyre and Paradox region but none was interested sufficiently to know more than that it did not show copper, silver, or gold in paying quantities.

In the early days a well known civil engineer of Golden, Captain E. L. Berthoud, while examining a coal deposit in the sedimentaries South of Golden, near Ralston Creek, found in the sandstone a yellow incrustation which interested him. He sent some specimens to The Smithsonian Institution, Washington, and received the information that the material on examination proved to be a uranium mineral, unknown but interesting. Some of these specimens were on exhibition at the World's Fair in Philadelphia in 1876 a year or so after the discovery was made. This statement was made to the author by Captain Berthoud in 1904 when upon inspection of some carnotite specimens from the McIntyre region at the Colorado School of Mines, the identity of carnotite and the ore from Ralston Creek was established. Mention was made at the same time of a publication by him on this form of uranium in Colorado. A search lead to the discovery of an article published by E. L. Berthoud in the *Proceedings* of the Philadelphia Academy of Natural Science, August 14, 1875, Vol. 27, pp. 363-365. The title of the publication is "On the Occurrence of Uranium Silver, Iron, etc., in the Tertiary Formation of Colorado Territory"—mention is made therein of a "green ochrey powder" and a uranium contents of two-tenths to two per cent.

In 1899 the Rare Metal Mining and Mfg. Co., of Denver, was founded by Messrs. Charles Poulot, analytical and technical chemist, and Chas. Voilleque, business manager. While the energy of these gentlemen was not confined to uranium alone their interest quickly centered about the pitchblende deposits of Gilpin County. In 1899 they operated unsuccessfully in Russell Gulch and in September of the year an option was asked for on the carnotite properties of the McIntyre District, situated on the Dolores River about 80 miles north of the town of Dolores. The consideration was $22,000.00. It must be remembered that it cost, at that time, fifty dollars a ton freight to ship ore from the carnotite fields to New York. Furthermore there was but little demand for vanadium, and radium had not yet been discovered.

This option was not taken up but instead the activities of these gentlemen centered around the La Sal Creek from which, at a point near the Cashin Mine at Cashin, ore was shipped abroad containing as high as ten per cent. U_3O_8. It was from here that specimens of rich ore were sent to Friedel and Cumenge in Paris. The new uranium mineral was analysed, identified and named by these two.

In short time, however, the inevitable question arose of handling lower grade ore and experiments were conducted at the Cashin Mine which led to the building in 1901 of the first uranium extraction plant, at McIntyre Canon. A print of this mill is to be found in the Colorado State Bureau of Mines report 1906. Options were renewed with some of the principal interests in the previous option above mentioned and work was diligently prosecuted for one year. Mr. J. N. McBride part owner of the Cashin Mine, became interested in this enterprise. The process consisted of a dilute sulphuric acid leach and precipitation with sodium carbonate. The ore used was contracted for on a basis of 2 per cent. uranium oxide but 100 tons of ore containing 1·3 per cent. uranium oxide and 2·3 per cent. vanadium oxide, which lay in the mill in the fall of 1902, showed that this basis was not always insisted upon. At the end of one year of operation, Mr. Poulot withdrew and went to France taking with him a large quantity of concentrates which formed part of the consideration of the purchase of his interests by Messrs. Voilleque and McBride. The concentrates ran from 6 to 50 per cent. uranium oxide but probably averaged about 12 to 15 per cent. No attention was paid to the radium slimes which were thrown out on the dump or mingled with precipitate as the case of handling any particular ore suggested. Naturally the concentrates consisted principally of iron vanadate, sodium uranate, iron hydrate, and calcium carbonate. The capacity of the mill was 10 tons a day. The plan of operation was as follows:

The ore was ground to 20 mesh in a Krupp ball mill and then stirred with wooden rakes in oblong vats containing diluted sulphuric acid. Partial reprecipitation of ferrous vanadate on the ore was allowed to take place to insure close neutralization and to avoid a waste of sodium carbonate in the subsequent precipitation. The solutions were run by gravity to settling tanks, thence to a precipitation tank where sodium carbonate was added. After the concentrate had settled, the supernatant liquor was decanted and the slimy settlings were run into shallow pits in the sand outdoors, to drain and dry for packing and shipment. The concentrates found a ready market abroad. Power was obtained from a 10 H. P. upright engine with wood as fuel.

It is significant that the Krupps made inquiry at this time for a large order of uranium concentrates.

In the fall of 1902 and the spring of 1903 the writer and Mr. Chas. E. Carpenter operated the Poulot-Voilleque Mill experimentally under lease, with a process to be described below.

In the fall of 1903 and spring of 1904 the mill was operated experimentally by Messrs. Carpenter and Justin H. Haynes under the name of The Western Refining Company with a process which developed into the Haynes-Engle patents. The mill practically ceased operation shortly after this and was dismantled.

In 1905 the Colorado School of Mines was called upon by the State Bureau of Mines to make a report of the carnotite fields. This was done during the terms of office as Commissioner of Mines of Mr. E. Lyman White and published by him in the report of 1906. The edition of two thousand volumes was rapidly exhausted.

In 1906 the Haynes-Engle process was put into operation by a Denver company known as the Dolores Refining Company which also took over most of the forty or fifty claims around the district. A new mill was built by this company about a mile farther up the Dolores Canon. Operations ceased in 1907.

None of the above projects was based on radium recovery but on uranium with vanadium a growing issue.

For several years there were occasional shipments of good grade ore out of this region and the Paradox Valley, but in 1910 renewed activity began in the Paradox Valley through the operation of the Standard Chemical Company. This company shipped ore to their Pittsburgh refinery where the radium was extracted. Foreign demand led to larger shipments abroad also.

In the summer and fall of 1912 and the spring of 1913 The American Rare Metal Company acquired the abandoned claims and mill of The Western Refining Company and built a new mill on the site of The Western Refining Company mill. The company worked under the Fleck-Haldane-White patents, essentially the operation conducted by the first named in the Poulot-Voilleque mill in 1902, but with the recovery of the radium added. Unable to sell its products, because of the wretched market in 1913 and subsequently, the company ceased operations.

Alarmed at the increasing exportations of uranium ores, especially in 1911, the government of the United States in the Bureau of Mines assigned Dr. R. B. Moore and Mr. K. L. Kithil in 1912 to a study of the problem in general. This was embodied in the preliminary report Bulletin 70, issued in 1913. The work covered much additional field work and technology to that already published but specifically investigated old and new processes with a view toward radium recovery. The co-operative agreement of the government of the United States and the National Radium Institute led to the adoption of a new and boldly conceived method of extraction for which an admirably adapted plant was subsequently constructed and put into operation in 1914. Radium, uranium and vanadium are all recovered by this process which is outlined in detail in Bulletin 104 by Messrs. Chas. L. Parsons, R. B. Moore, S. C. Lind and O. C. Schaefer. Of considerable historic interest is the investigation by House and Senate Committees of the sixty-third Congress, made with a view of conservation of the carnotite fields. The hearings were issued in H. J. Res. 185 and 186, Jan. 19-28, 1914, and S. 4405, Fed. 10-24, 1914.

Except for work made possible under contracts drawn previous to August, 1914, carnotite and other uranium ores have had little stimulus during the war period.

With a number of extraction methods solved, the principal problem to be faced is the concentration of the very low-grade ores and mill residues, the usual problem which follows rapid exhaustion of higher grade shipping ores.

PHYSICAL AND CHEMICAL PROPERTIES.

Moissan first prepared the metal in fairly pure state.

1. By heating the double chloride of uranium and sodium with metallic sodium. Purity 99·4.
2. By electrolysis of the above double chloride fused.
3. By the reduction of the green oxide by carbon in the electric furnace. Purity 99·27.

In the last process he used a charge of 500 grams oxide, U_3O_8, and 40 grams carbon.

The current used was 800 Am. 405 V. and the duration of operation 8 to 10 minutes. The yield was 350 grams metal which assayed: 99·52 uranium, ·005 carbon, ·421 slag.

It is a white, non-magnetic metal, not especially hard. The specific gravity is 18·7. It takes up carbon and can be tempered. It unites with carbon on strong heating forming a carbide of the composition U_2C_3. The latter can be made direct by heating 500 grams oxide U_3O_8 with 600 grams carbon in the electric furnace. This compound melts at high temperature. It has a specific gravity 11·28 and in appearance resembles bismuth. Water decomposed it with formation of methane and liquid hydrocarbon.

Uranium rusts like iron at ordinary temperature but decomposes water at 100° C. with evolution of hydrogen. It is soluble in mineral acids.

The metal unites readily with fluorine, chlorine, bromine and iodine. In finely divided state it burns readily to the oxide in a current of oxygen.

There are several states of oxidation but the common state is hexavalent. Common salts of uranium contain the radical UO_2. Such salts are yellowish green in color and fluorescent.

Minerals and Ores.

There are about 30 minerals which contain uranium as a constant constituent. Of these the following are of commercial importance: Uraninite or pitchblende, carnotite, autunite and torbernite.

Uraninite or pitchblende is an impure uranyl-uranic oxide U_3O_8, specific gravity 7·2. The former term is used for the crystalline variety and the latter term for the amorphous variety.

Color: pitch black; brownish; sometimes with a grayish or greenish cast.

Streak: brown-black; olive green or grayish.

Luster: dull, submetallic greasy; pitchlike.

Fracture: conchoidal; brittle.

Hardness less than quartz. Not scratched by a knife.

An analysis is:

Uranium oxide, U_3O_8	75·23	per	cent
Lead sulphide, PbS	4·82	"	"
Silica, SiO_2	3·48	"	"
Lime, CaO	5·24	"	"
Magnesia, MgO	2·07	"	"
Sodium oxide Na_2O	2·05	"	"
Ferrous oxide, FeO	3·10	per	cent
Manganous oxide, MnO	·82	"	"
Carbon dioxide, CO_2	3·32	"	"
Water, H_2O	1·85	"	"
	101·98	"	"

In addition to these, pitchblende contains also a small quantity of the rare gas helium.

The following common minerals are likely to be mistaken for pitchblende by prospectors:

Obsidian or volcanic glass, which differs from pitchblende in its lightness, glassy luster, and light streak.

Magnetite, which differs from pitchblende mainly in that it is attracted by the magnet.

Hematite, which differs from pitchblende mainly in possessing a red streak.

Carnotite is urano-vanadate of potassium or usually, as has been more recently established, a mixture of true carnotite $2UO_3. V_2O_5. K_2O+\times H_2O$ and tjuyamunite $2UO_3. V_2O_5. CaO +\times H_2O$, a urano-vanadate of lime.

An analysis is:

Potassium oxide, K_2O	10·37	per	cent
Uranium oxide, UO_3	63·54	"	"
Vanadium oxide, V_2O_5	20·12	"	"
Water, H_2O	5·95	"	"
	99·98	"	"

In its purest form carnotite is of a bright canary yellow or citron yellow color. It is soft and can be scratched with the finger nail. It is easily polished and has a high gravity. However, such specimens are rarely met with. As a rule deposits of commercial value consist of the yellow substance deposited on sand grains in sand stone, or as flour-like incrustation on shale or intermingled with clay-like substance. For field test, and practical purposes the following directions are issued to prospectors in the Prospecting Course at the Colorado School of Mines.

Uranium and radium are found together. Like lead, zinc and sulphur they are elements.

The list of minerals in which they occur is numerous, but they are obtained from only a few minerals all of which are found in considerable quantities in Colorado, namely: Carnotite, pitchblende (uraninite), samarskite.

Carnotite contains uranium, vanadium and radium. It is found as a canary yellow powder, filling the voids and encrusting the sand grains of some sand rock deposits. Sometimes it is recognizable only as a yellow flake here and there exposed in the broken rock, but often the entire specimen is colored yellow, and very high-grade ore (which is unusual) forms a yellow mass which is rather soft and easily cut and fine grained.

Color: Sometimes the yellow is hidden by a predominating green or blue, due to presence of copper. Again the color may be buff or reddish due to a compound of iron.

It is therefore, impossible to tell for certain what is carnotite and what is not but by the above description the ground to be covered is considerably narrowed.

FUTHER IDENTIFICATION.

Since carnotite carries vanadium, detection of the presence of vanadium would add to the evidence of the physical properties above. Fortunately a very simple test covers this point.

Test: In case of ore, supposedly low grade, about as much ore is taken in ground form (ground down about as fine as the sand grain), as could be heaped on a dollar and this is then heated for a few moments in a porcelain casserole, with dilute nitric acid. The liquid is filtered off and to the filtrate is added a little hydrogen peroxide. A cherry red color in the solution should follow. This indicates the presence of vanadium, which, together with the fact that the ore in physical appearance corresponds to carnotite, is a very strong and nearly conclusive evidence that the mineral is carnotite. However, specimens have been found which are from greenish yellow to canary yellow in color and which give a strong cherry red color with hydrogen peroxide in the last test but which do not contain any uranium, and of course do not contain any radium. Such material is found, for instance, in considerable quantity at Garo, South Park, Colorado. In original and in ground form some specimens strongly resemble carnotite. They dissolve in nitric acid readily, leaving the sand grains behind, forming the characteristic solution of vanadium with hydrogen peroxide, but they do not show a uranium test and they show very little, if any, radio-activity.

In the end it becomes necessary, therefore, to continue the test from the cherry-red color to a point where uranium may be detected and this is done in the following way:

The filtered cherry-red solution (see above) is treated with ammonium hydrate (household ammonia will do), and as soon as a precipitate permanently forms on stirring this solution, a level tablespoonful of ammonium carbonate powder is added and stirred in for a few moments. The solution is then warmed until it becomes uncomfortable to the touch, but it is not to be boiled. This solution is filtered and the filtrate is collected in a flask and boiled until the odor of ammonia is slight. A yellowish, heavy powder may deposit during this operation. If so, it is filtered off and dissolved in the smallest quantity of dilute hot nitric acid, which solution is then boiled and diluted. When cool, ammonia is added until upon stirring, the solution smells strongly of ammonia. A canary yellow precipitate at this point indicates uranium. If the precipitate should be small and rather reddish in cast, the presence of uranium is doubtful. If the precipitate should be greenish in color, but large, uranium is probably present, together with some copper, which has discolored it.

It will be well to practice this test first with specimens known to contain uranium and vanadium.

A further test for both pitchblende and carnotite is the following:

Since uranium and radium both emit penetrating rays which will affect a photographic plate, it is very easy to perform this test. Enclose tightly in a black heavy paper, so as to keep out the light, a photographic plate, noting first which is the film side of the plate. Lay the covered plate down with film side up and place upon it a key or some flat metal object. Then lay the sample of ore upon the key. Place the whole in a drawer or away in the dark, because some day light may leak slowly through the paper and affect the plate. After it has remained in this position for three days, develop the plate and find if an image is obtained similar to the object. In that case the sample may be worthy of a laboratory test.

Autunite is a double phosphate of lime and uranium.

Its formula is $2(UO_2)_3\ (PO_4)_2 + \times H_2O$. The formula requires 60·4 per cent. uranic oxide UO_3. It occurs in nearly square crystal plates of a sulphur yellow color.

Torbernite is a double phosphate of copper and uranium.

Its formula is $2(UO_2)_3\ (PO_4)_2 + Cu_3(PO_4)_2 + \times H_2O$. This gives a calculated contents of 61·2 per cent. uranium trioxide UO_3. It occurs in square plates of brilliant shades of green.

Pitchblende is found in Bohemia, Saxony, Cornwall and Colorado in commercially important quantities. There are some other localities in which the mineral occurs but these are of mineralogical interest only.

By far the most important occurrence is in three mines at Joachimsthal, Bohemia on the southern slope of the Erzgebirge. The country rocks consist of slaty and calcareous mica schist and crystalline limestones. Dikes of quartz porphyry and also basalt and phonolite traverse the area in a north to northwest trend.

The silver-cobalt veins form two groups, i. e., The "Morgengänge" striking E.-N.E. with a dip 60°-80° north, and the Mitternachtgänge, striking N.-S. with a dip 45°-85° west or east.

The first group is unimportant. Of the 29 veins in the second group 22 have produced uranium. The veins attain a thickness of less than 3 feet (30 cm.). The gangue varies with the different veins but consists of clay, quartz hornstone, calcspar and dolomite. The country rock near the fissure also carries very small quantities of uranium. Johanngeorgenstadt lies on the northward continuation of the Joachimsthal contacts. Since much of the ore mined here has gone into the hands of mineral collectors the place is somewhat better known than Joachimsthal though of much less consequence as a uranium ore producer. The rock is of gray gneiss. The pitchblende is associated with nickel-cobalt minerals.

In Cornwall the uranium ores are closely associated with nickel-cobalt minerals as in Bohemia and Saxony and they belong to the same period of vein formation.

There are twenty-three mines in which uranium occurs but only a few of these are important as uranium producers. Most important is the South Terras Mine several miles west of St. Austell. The vein "The Jim Lode" is from 2 to 4 ft. wide and uranium occurs as autunite and torbernite, principally in stringers which attain a width of 7 to 8 inches, on the upper levels, and as pitchblende in the lower levels.

The Trenwith Mine at St. Ives has produced a number of tons of pitchblende which were worked up under the direction of Sir Wm. Ramsey by the British Radium Corporation at Limehouse, London.

The deposits of Gilpin County, Colorado, lie on Quartz Hill near Central City in a belt 1000 ft. wide and one-half mile long. The veins have a N.E-S.W. trend and occur in a district of gneiss and crystalline schist traversed by numerous andesite-dikes. Granitic dikes while not numerous are present and are believed to be intimately associated with the pitchblende. The ore is not found with gold in any quantity. It is associated with pyrite and sphalerite principally. Small lenses of several hundred pounds, running high in uranium oxide but free of all other minerals except hair-like films of pyrite, have been found. The veins have a width of several feet with irregular streaks of pitchblende 4 to 20 inches in width. An average of the high-grade is about 30 per cent. U_3O_8. Picked samples and some of the lenses found show about 80 per cent. The average low-grade will vary from 1 and 3 per cent.

In Portugal on the east side of the Sierra d'Estradelle about one hundred and fifty uranium-bearing localities have been observed in the great granite belt that stretches from the northwest corner of Portugal across the Spanish border. Several companies have entered the field, most important of which is the French Societe l'Uran which operated the Rosmaneira mine in the locality which lies between Sabugal and Guarda.

The veins are in reality pegmatite dikes extending into the Cambrian schists. Their width is from 1½ to 3 feet and more, and the uranium minerals are autunite and torbernite. The ore is very low grade, around 0·5 per cent. uranium oxide which necessitates a refining operation near the mines.

There are two localities of importance in South Austalia. One at Radium Hill twenty miles southeast of Olary Station on the Petersburg Bunker Hill R. R., was discovered by Mawson in 1906. The lodes consist of two dikes 25 to 45 feet apart. They lie in a gneissoid micaceous granite and granite schist traversed by dikes of granite and diorite. The mineral is carnotite associated with titanium and rare-earth minerals. The uranium oxide contents vary from to 2 to 1·3 per cent. approximately and the property is operated by the Radium Hill Co. The refinery is at Woolwich (Sidney), New South Wales. The other deposit is situated about 80 miles southeast from Farina Station on the Great Northern Railway at Painter Hill.

The country rock is altered sedimentary and the minerals are autunite and torbernite principally. The properties are operated by the Radium Extraction Company. The uranium oxide contents vary between 0·2 and 0·5 per cent.

The greatest uranium and radium-producing deposits lie in carnotite areas southwestern and western Colorado and southeastern Utah.

The principal uranium-producing counties in Colorado are San Miguel, Montrose and Mesa. In Utah, Grand and Emery counties lead. Rio Blanco and Routt also have carnotite bearing deposits at Coal Creek and Skull Creek respectively.

The McIntyre Canon district, the Paradox valley, the San Rafael Swell near Green River, Utah, and the Gateway region have in turn all become localities of activity and importance in the last fifteen years. Descriptions of these in great detail have been published by the Colorado School of Mines, the U. S. Bureau of Mines and the U. S. Geological Survey so no attempt will be made to go into detail here.

In general then the principal Colorado deposits lie on the San Miguel Plateau and are embraced by a line drawn south fram Gateway, Mesa county through Hydraulic and Naturita, southwest through Cedar, northwest to the border at La Sal Creek and north to Gateway. In this area we find the McIntyre which has been extended recently and in which early milling operations took place. Groups of claims are found on both sides of the Dolores River about seven miles down the river from the junction of the Dolores River and Disappointment Creek. Some rich deposits have been found here.

Attention has been called to claims on the La Sal Creek near Cashin. Over the La Sal Creek divide lies the Paradox Valley on both sides of which carnotite deposits have been found in quantity. They lie principally about Long Park on the north side and directly south on the south side of the valley. Here the greatest activity has taken place in late years beginning in 1910 to 1911. From here also, most of the ore has come from which radium has been extracted in the United States by the National Radium Institute of Denver and the Standard Chemical Company of Pittsburgh.

Both sides of the Dolores River show good carnotite claims near Hydraulic. To the west of Hydraulic lies Uranium. Some of the first ore shipped in quantity was taken from the Copper Prince mine on Rock Creek at this point. To the north at Gateway in Mesa county important developments in the last two years have proved the value of the region.

The Utah deposits of importance lie near Thompsons, Grand county, and in Emery county southwest of Green River in the San Rafael Swell.

In general the mineralogical and geological phenomena are nearly alike throughout the important Colcrado regions. The ore occurs in the sandstones of the Jura-trias and is mainly in form of a fine incrustation on sandstone intermingled with more or less argillaceous matter. Not infrequently rich pockets occur, or trees impregnated with the fine yellow material. In some places where weathering has worn down the surface to the carnotite deposits, mining is not so difficult, but at best it is hazardous owing to the irregularity or bunchy nature of the ore. Claims with good prospects often prove valueless and claims with poor prospects may yield well.

Concentration and Metallurgy.

Necessity for mechanical concentration has not been felt until within the last few years. The rise in price due to use of the radium contents has made it possible to ship ores ranging around 2 per cent. uranium oxide. Formerly concentration of a 2 per cent. ore at the spot was necessary in order to get the advantage of the higher price of uranium oxide which was the chief product. In the early years of 1900-1910 ore containing 4 per cent. uranium oxide was shipped from the Georgetown claim, McIntyre district, with loss to the sender. With the larger part of the ore running from 0·5 to 1 per cent. uranic oxide methods of concentration were devised by the Standard Chemical Company and the National Radium Institute. In 1902 the writer had conducted experiments on ore of 1·3 per cent. uranium oxide contents, 100 tons of which lay in the Poulot-Voilleque mill. The ore was subjected to abrasion in sacks loosely filled and kneaded to loosen the carnotite particles. The mass was then elutriated and the products dried and assayed.

The results were published in the report of 1905-06 and showed that 33·6 per cent of the uranium oxide was recovered in form of a slime containing 7·3 per cent. uranium oxide. In this case the ore was ground to 20-mesh. A second sample of higher grade ore ground to 40-mesh gave a 42·5 per cent. recovery in a concentrate which showed 12·00 per cent. uranium oxide. The concentration ratio in the first was 6:1, in the second example 4:1.

Dry concentration has proved more successful and the two concentration mills of the Standard Chemical Company and the National Radium Institute, are based on this principle. The ore is crushed, ground to 30-mesh dried and stored. It is then subjected to the action of cyclone blowers and the dust is caught. The dust constitutes the concentrates which will run 3 and 4 per cent. uranium oxide from an ore running one per cent. and less. The recovery is about 50 to 75 per cent.

In the end there still remains the pretty problem of removing the remaining carnotite from the already mined and extracted tailings. It must be remembered that 0·25 to 0·5 per cent. carnotite in this state is worth a considerably higher percentage in undetermined and unmined ore.

The mechanical concentration of pitchblende is a different matter. The ore in nature varies so much that each kind has its own special treatment. Jigging and table concentration have been tried in Gilpin County ores but with indifferent success in some instances. High grade concentrates were made it is true but loss by sliming was considerable.

The further refining of uranium ores for uranium now accompanies radium extraction so that at present uranium is a by-product.

The usual procedure takes advantage first of the solubility of the mineral direct or after a simple preliminary treatment, in acid. Second the solubility of the carbonate in excess of sodium carbonate whereas the impurities lime, iron, aluminium compounds, etc., remain insoluble; third the reprecipitation of uranium in form of sodium uranate from this solution either by neutralization with sulphuric acid or caustic soda.

The old Patera process used for many years at Joachinsthal roasts the ore to drive off sulphur and arsenic. This is followed by a roast with 15 per cent. soda ash and 2 per cent. sodium nitrate on a reverberatory hearth for five hours.

The mass is washed and leached with sulphuric acid, one pound to 3 pounds residue containing 45 per cent. of uranium oxide. A small amount of nitric acid is also added. Sodium carbonate is added in excess to the boiling solution.

The lime, magnesia, iron and alumina compounds are filtered off and to the golden yellow filtrate, sulphuric acid is added to complete precipitation of the uranium in form of yellow sodium uranate. Sodium sulphate is used instead of sodium carbonate at present it is stated.

Another process dissolves the ores in a sulphuric-nitric-acid mixture and proceeds as above.

In still another method the pitchblende is roasted with lime which treatment causes the uranium to go into solution readily with sulphuric acid. The remaining treatment is similar to the above.

Quite similar treatment is used for the recovery of uranium from carnotite ores, mechanically made concentrates and chemically prepared concentrates.

The process used in Denver at the National Radium Institute treats the carnotite ores and air-blast concentrates with nitric acid. After precipitation and filtration of the radium as sulphate from the clarified solution, the nitric acid solution is added to a boiling solution containing an excess of sodium carbonate. Boiling is continued for three hours. The precipitate of carbonates of calcium and magnesium together with hydroxides of iron and aluminium, is filter pressed and rejected. The alkaline solution containing uranium is neutralized with nitric acid to a point of precipitation when caustic soda is added to complete precipitation of uranium as sodium uranate. Usually this precipitate carries almost 7 per cent. vanadium oxide which may be removed in the old Rose method principle of making the green oxide of uranium from sodium uranate by heating the latter with ammonium chloride. Vanadium volatilizes during the process leaving the uranium oxide free.

By fusion with two to two and one-half times its weight of sodium sulphate the sodium uranate remains unchanged chemically and the vanadium contents are reduced to 0·5 per cent. in one operation.

The author has obtained fairly good results by dissolving the sodium uranate in sulphurous acid. On boiling, the uranium is precipitated as a heavy crystalline easily filtered basic sulphite while most of the vanadium remains in solution. The yellow sulphite gives the green oxide or ignition.

Another carnotite process which recovers uranium is the Haynes-Engle which consists of a hot leach of the ore with sodium carbonate, filtration, precipitation of the uranium from the resulting clarified solution with caustic soda. The product is sodium uranate. Radium is not recovered.

The Fleck-Haldane process treats the ore hot with dilute sulphuric acid, reduces iron to ferrous condition with sulphur dioxide, neutralizes the clarified solution with ground limestone, filters and completes precipitation with more ground limestone. The uranium is present in complex form. Concentrates run from 12 per cent. U_3O_8 when very low-grade ores are used to 25 per cent. U_3O_8 when ore of 2 to 3 per cent. is used. The concentrates are refined by methods already described. The radium is recovered in form of a radium slime. A second process proposed by these two makes use the solvent power of sulphurous acid. The remaining procedure is much the same.

Most other processes for carnotite not already described are modifications of one or the other of these three methods.

In Olary, South Australia, the Radcliff process is used. A fusion of the ore is made with sodium bisulphate. The fused mass is crushed, leached and uranium solution containing radium slimes in suspension is drawn off and clarified. The remaining treatment with excess sodium carbonate and subsequent precipitation has been described.

In Portugal at the refinery of the Societe' L'Uran the ground ore is leached with hydrochloric acid and the uranium, radium, iron and copper are precipitated with powdered limestone. The precipitate is refined by well known methods.

USES.

Uranium salts are used in laboratories as reagents; in photography; in medicine; for making greenish yellow opalescent glass in art ware; in coloring porcelain yellow and black; in stamping Welsbach mantels and in metallic form as a catalyzer in making ammonia.

In making special steels, uranium has been found to impart the same properties as tungsten but except for the last year or so the latter has been cheaper and the output assured and steady. It has been stated on good authority recently that a small percentage of uranium metal combined with chromium gives excellent results, equal to tungsten steel.

This may absorb the over-supply of uranium on the market and insure a constant output.

OUTPUT AND PRICES.

Austria from 1854 to 1914 produced 496.5 tons (metric) of ore averaging 50 per cent. U_3O_8 according to one authority.

Annual Government reports from 1885 to 1913, however, show a total production of 766 metric tons of ore from which 208 tons uranium salts were made. The two reports correspond in fact though not in figures, for the tonnage of salts approximates 496.5 tons of ore figured on a 50 per cent. basis. Practically the entire output is from Joachimsthal.

Germany, from 1878-1912 produced 1,455 tons of ore reported jointly as uranium and tungsten ore. One authority estimates that the total output, mostly from Johanngeorgenstadt, from 1840 up to 1914 is only 20 metric tons pitchblende.

The United Kingdom has produced 576 metric tons of uranium ore since 1856. Much of this was low grade. The authority for this estimate states that the total U_3O_8 production of Cornwall equals about one-sixth that of Joachimsthal or approximately 40 tons. Annual Government reports show a total of 963 metric tons of ore produced from 1892 to 1913. Again the figures do not agree but the facts do, as is seen in the following computation. The value of ore amounting to 344 tons produced from 1892 to 1901 is given in government reports at about $64,465. Assuming a value of two dollars a pound for U_3O_8 contained, the number of pounds oxide produced in that period is 32,232. This would bring the percentage of uranium oxide in the ore somewhat below 5 per cent. Again assuming a uniform uranium contents in the output of the following years, then 5 per cent. of 963 tons would bring the total to 48 tons of uranium oxide, a figure which agrees well with one-sixth of the Joachimsthal figure or roundly calculated, 40 tons.

In the United States shipments prior to 1900 were mainly pitchblende. From that time on most of the output refers to carnotite, concentrates and ore, although pitchblende both high and low-grade was shipped out of Gilpin County in 1906 and succeeding years.

Published statistics, however, appear to be unreliable

It is estimated that up to August, 1914, 5,500 tons of uranium ore were produced. This amount is said to represent 105 tons of uranium oxide.

Mineral Industry reports production from 1897 to 1902 as follows:

1897	17	short	tons,	valued	at	$ 9,010
1898	33	"	"	"	"	16,500
1899	43	"	"	"	"	21,500
1900	153	"	"	"	"	45,900
1901	375	"	"	"	"	102,500
1902	810	"	"	"	"	.....

It has been stated that the tonnage of Gilpin County, based on high uranium contents, is about 20 tons. If so it is questionable whether the figures for 1900, 1901 and 1902 are correct. In 1900 and 1901 the only production to the author's best knowledge was a few tons of ore and concentrates averaging 12-15 per cent. uranium oxide prepared at Cashin and McIntyre by Messrs. Poulot and Voilleque. Records of this company in the author's possession may not be complete but shipments made in July, September, October and December of 1900 and in January and April, 1901, show about 16 tons. In the light of published statements the large tonnage of 1902 is not clear. The carnotite deposits that year were practically unproductive.

Most of the production has been made since 1910. In all probability the estimate of 5,500 tons equal to 105 tons uranium oxide will not be very far wrong if the tonnage is taken to date.

Uranium ores sell on a uranium oxide basis, at present just as they did before the discovery of radium. Prices have advanced materially since carnotite became a source of radium. The basis is convenient and recognizes the uranium-radium ratio.

Prices for concentrates in 1900, 1901 ranged from $1.50 to $1.75 a pound of U_3O_8 contained in a 12-15 per cent. concentrate.

The governing price for sodium uranate in 1906 was around $2.40 a pound oxide in an 85 per cent. concentrate.

Two per cent. carnotite and even higher grade could not be shipped at that time profitably.

In 1901 prices for ore were quoted as follows, presumably F. O. B. Denver:

10	per cent	U_3O_8..........	$1.75	pound	oxide	contained
10-15	"	"	1.80	"	"	"
10-20	"	"	1.90	"	"	"
20 +	"	"	2.00	"	"	"

In 1914 the following prices ruled:

2	per cent	U_3O_8......	$2.00	pound	oxide	contained
3	"	"	3.00	"	"	"
20-30	"	"	3.25-3.50	"	"	"
50-70	"	"	4.25	"	"	"

In other words in 1914 a 2 per cent. ore brought $80, whereas in 1901 a 2 per cent. ore was not wanted; in 1914 a 3 per cent. ore brought $240, whereas in 1901, 3 per cent. ores were not in demand; in 1914 a 20 per cent. ore brought $1,300 or nearly double the same grade of ore in 1901.

It is readily seen why concentrating plants were necessary in former years and how they worked against great odds.

PROCEEDINGS OF THE COLORADO SCIENTIFIC SOCIETY
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MINERALOGICAL NOTES NO. IV.

THE IDENTITY OF BLACK RUTILE AND STRUEVERITE

By Dr. William P. Headden.

(Read at the meeting of the Society, November 4th, 1916.)

In 1891, I published in the American Journal of Science, Third Ser. Vol. 14, p. 249, an analysis of a mineral under the designation of "Black Rutile." The crystallographic description was given by Prof. L. V. Pirsson.

The specimen which formed the basis of the article was a small one, found in a miscellaneous lot in the collection of the South Dakota School of Mines. This lot consisted of samples from unknown localities and there was no pretense of identification. I had no knowledge of the source or association of the mineral.

The analysis of the sample gave me trouble and at first I held it to be a new mineral, scarcely belonging to the rutile group, as I readily recognized the abnormal deportment of the titanic acid which I recognized as present. I take it up again because of the mistake that I made in regard to its composition, and because I was not satisfied with the identification of my "black rutile" as Strueverite made by Messrs. F. L. Hess and R. C. Wells, American Journal of Science, Fourth Series, Vol. 31, 1911, p. 432.

I described the mineral as a black rutile, giving the whole of the acids as titanic acid. This was a mistake which I did not believe until recently, and which is interesting enough to bear being given in some detail. I noted that the acid did not deport itself as titanic acid usually does, but as the potassic bisulfate melt went into solution in cold water I made special record of the fact, that tantalic and columbic acids could not be present. This was my judgment at the time and it continued to be my conviction until the past summer when wearied by the perplexities of agricultural chemistry, I turned to this subject for a change and to satisfy my desire to prove myself correct in my former judgment. The conclusion that tantalic and columbic acids were absent, because the melt was soluble in cold water, was wrong, though it was justified by the statements of our manuals, and was in conformity with my experience in analyzing columbiles, tantalites and other minerals containing these acids. Heinrich Rose in his Manual of Analytical Chemistry, writes of the separation of tantalic acid from zirconia and titanic acid as follows: "By fusing the compound with potassic bisulfate and treating the melt with cold water, one obtains only a part of the zirconia or titanic acid in solution, and therefore one must heat the residue repeatedly with concentrated sulfuric acid or fuse it with potassic bisulfate till no more zirconia or titanic acid is dissolved out of the tantalic acid."* The following language regarding the deportment of tantalic and titanic acids is still retained in our manuals of qualitative chemistry so far as I know: "With potassium bisulfate, it fuses to a colorless mass; and if this be treated with water, tantalic acid combined with sulfuric acid remains undissolved (difference between tantalic acid and titanic acid, but it cannot be made the ground of a method of separation)."†

These citations show that tantalic acid was considered insoluble in the solution of the potassic bisulfate melt, and it is common knowledge that tantalic and columbic oxids are separated from the bases with which they may be combined by this method, not more than traces of these oxids going into solution.

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*Heinrich Rose, Handbuch der Analytischen Chemie, Sechste Anfeage, Vol. II, 1871, p. 331. Author's translation.

†Fresenius Manual of Qualitative Chemical Analysis, p. 187. Translated by Horace L. Wells. 1900.

I had but a small amount of material, and made but two or three fusions of the mineral. My recollection of the matter is that the second portion gave an opalescent solution, but in no way resembled the separated tantalic or columbic acid as obtained by the fusion of columbite or tantalite. The solution was, as I recall it, very similar to the solution given by a potassic bisulfate melt of titanic acid, which has been heated till the mass is nearly neutral, both in appearance and in the amount of undissolved acid. It is, of course, impossible for me, at this time, to tell exactly how I manipulated the fusion of the mineral, as this work was done 25 years ago, but my notes state of the first fusion, "completely soluble in cold water, hence neither tantalic nor columbic acid can be present."

A little over a year ago, I received through the kindness of Mr. F. L. Hess, two samples of strueverite, one from the Etta Mine, Pennington Co., South Dakota, and the other from Salak North near Kuala (Kangsar), Perak, Federated Malay States. The Etta sample was, of course, of the greater interest to me as there was a probability that my sample came from this locality, for the Etta mine was a favorite collecting place, especially in its early history, besides all sorts of minerals and ores were brought to the School of Mines for assay or identification. It was very probable indeed that my sample might have come from this locality, provided it was really identical with the mineral strueverite, which I still doubted, though the case made out by Messrs. Hess and Wells seemed pretty strong, and the sample received from Mr. Hess resembled my original material to such an extent that, had I not still believed that tantalic acid would not go into solution under the conditions stated, I would have forthwith acknowledged the identity of the minerals and the Etta Mine as the locality from which my original sample was obtained.

My notes, and my recollection of the deportment of the potassic bisulfate melt, agreed in regard to its solubility in cold water. It is quite certain that I did not use a dilute sulfuric acid in dissolving it or my notes would not read cold water. It is now common knowledge that a bisulfate melt, of rutile for instance, is easily soluble to a clear bright solution in 5·0 per cent sulfuric acid, but I am sure that I did not use such an acid as I, at that time, was especially interested in the analysis of columbites in which the melts were always disintegrated with water.

The receipt of these samples together with my doubts in regard to the solubility of tantalic acid as already stated, led me to avail myself of the first opportunity to study the matter further, but it is not my intention to present analyses of the material received from Mr. Hess, though it enabled me to acquaint myself with the deportment of strueverite. I found that it was nearly all soluble in cold water after fusion with potassic bisulfate, and while I did not succeed in getting it wholly into solution, it was perfectly clear that its deportment is entirely different from that of a tantalate and while we know that sulfuric acid throws tantalic acid out of its solution, the bisulfate melt of this mineral is easily soluble in a 5·0 per cent solution of sulfuric acid, with only a very slight residue, probably due to the small amount of silica and possibly stannic oxid. This solution is as bright as a solution of rutile, obtained in the same manner, and remains clear apparently indefinitely. I am not sure whether this was stated by Messrs. Hess and Wells or not, as their article is not available to me at this time. These results led me to a revision of my views relative to the improbability of the presence of tantalic acid in my black rutile, especially as I have found many bisulfate melts of rutile or titanic iron quite as difficultly soluble in water as the melts of this mineral, which certainly gives no indication of the presence of 40·0 per cent of tantalic acid.

There is no difference, however, in the deportment of the melts obtained by the bisulfate fusion of the two minerals, rutile and strueverite, which has not been previously noted, so far as I know. The bisulfate melt of rutile dissolved quite readily in dilute sulfuric acid, 5·0 per cent, to a clear bright solution. I find that the sulfuric acid can be replaced by a 2·0 per cent solution of potassic bisulfate, as the trouble usually met with is not one of solution, but one of hydrolization, which the 2·0 per cent of potassic bisulfate suffices to prevent. This was suggested to me by watching the solution of a bisulfate melt of rutile, which had been fused till the mass was too nearly neutral and which yielded a very turbid solution. I have not found this to be the case with the strueverite which is due, I take it, to the presence of tantalic acid, whose hydrolization the small amount of potassic bisulfate added does not suffice to prevent entirely. The addition of sulfuric acid, however, gives with this mineral, as well as with rutile, a perfectly bright and almost complete solution, which remains clear and bright indefinitely. This is altogether different from the deportment of the melt obtained by fusing columbite with potassic bisulfate. This melt when treated with the same amount of water, containing 3 c.c., concentrated sulfuric acid in each 100 c.c., which was the strength of the sulfuric acid used in the case of the strueverite, did not even disintegrate, but yielded a pure white mass of acids, columbic with a little tantalic, having the exact form of the melt, even to the sharp edges and those irregularities of the melt caused by the fused mass running up the sides of the crucible. I did not try this with tantalic acid or a tantalate, because I had no material which I felt willing to sacrifice for this purpose.

The dilute sulfuric acid solution of strueverite does not become turbid on standing and may be heated to boiling without becoming turbid, but if the boiling be continued for a few minutes a precipitate begins to form and increases as the boiling is continued. The precipitate is fine granular and filters easily. The filtrate gave a heavy precipitate with ammonia though the solution had been boiled for 35 minutes.

The fact that a dilute sulfuric acid solution, made in the cold, remained clear on being heated to boiling, suggested the feasibility of using warm or even hot sulfuric acid. Warm, 5·0 per cent sulfuric acid was tried with success. The solution of the melt was but little more turbid than the cold water solution of its mate.

I feel that these peculiarities in the deportment of this mixture of acids, principally titanic and tantalic acids, is of sufficient interest to justify the presentation of the preceding details. The solubility of this mixture, wholly or very largely complete in water, led me astray in making the analysis of the black rutile from the Black Hills in 1891.

I have never seen the article of Messrs. Hess and Wells, but I have the discussion of their analysis by Waldemar T. Shaller who concludes that the material that I analyzed in 1891 was identical with that analyzed by these authors for the following reason, i.e., the specific gravity was the same, and approximately a whole unit too high for an ordinary rutile. He further pionts out that the percentages given for ferrous and stannic oxids are practically identical in the two analyses. This conclusion is correct. In looking up the remnants of my specimen, I found that I had preserved the supposed titanic acid obtained in my original analyses. There was between 4- and 5-tenths of a gram of it. I submitted this to analysis, which, while only approximate, leaves no doubt about the identity of my original black rutile and the strueverite described by Hess and Wells from the Etta Mine.

The re-statement of my analysis becomes as follows:

		Wells' Analysis
TiO_2 (Too high)	52·30	49·00
Ta_2O_5	34·39	35·70
Cb_2O_5 (Too low)	4·04	6·70
SnO_2	1·35	1·30
FeO	8·01	7·30
MnO	Trace	
	100·09	

I cannot claim any great degree of exactness for the separation of the acids in my analysis, but the results serve fully for the identification of the mineral which is the object had in view in this note. My titanic acid is higher than Wells' and the tantalic and columbic acids are each lower. It is possible that there were differences in our samples, but I think it is more probably due to the small quantity of material with which I had to work and the method that I used, as my aim was not so much to obtain an analysis which should be correct in details as to establish the identity of the minerals, and still more to ascertain the cause of the anomalous reactions which led me astray in regard to the presence of tantalic acid. I was fully aware that my supposed titanic acid deported itself in an unusual manner and considered it probable that it was mixed with zirconia, but I was unable to establish the presence of this element and not knowing the deportment of a mixture of titanic and tantalic acids, I depended upon the literature known to me, and on my experience with tantalic acid, as conclusive that it would not go into solution in water after fusion with potassic bisulfate. Had I used dilute sulfuric acid to bring the melt into solution, I would not have obtained a precipitate on heating to a temperature below boiling, for an acid solution of a mixture of these acids may be heated to active boiling before precipitation takes place.

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ON THE ESTIMATION AND SEPARATION OF TITANIUM, COLUMBIUM, TANTALUM, AND ZIRCONIUM

By Dr. William P. Headden.

(Read at the meeting of the Society, November 4th, 1916.)

We have found, up to the present time, no simple and easy method of detecting these elements when two or more of them are present in the same compound. This is especially true if titanium is one of those present. I have referred to the effects of titanic acid upon the deportment of tantalic acid when fused with potassic bisulfate in a separate note. In this case the solubility of the melt in cold water led me to an entirely erroneous conclusion, i.e., that tantalic and columbic acids were absent because the melt was soluble in cold water, whereas, there was nearly 200 milligrams of tantalic in the one-half gram of mineral taken for analysis. I have since learned that a mixture of titanic and columbic acids deports itself in the same manner. I have repeatedly obtained an almost perfect solution of a bisulfate melt of a mixture of titanic and columbic acids in 200 c.c. of water at a temperature of 70° or 80° C. The ratio of titanic to columbic acid in this mixture was 6:5.

Tantalic and columbic acids are quite completely separated from the bases with which they may be combined, by fusion with potassic bisulfate, and subsequent treatment with cold water. The addition of 5·0 per cent of sulfuric acid does not change this deportment. Neither of these statements is true if titanic acid be present. In this case, the whole of these acids may go into solution in cold water, though there is usually more or less turbidity, similar to that caused by the separation of metatitanic acid on the solution of a melt of titanic acid in potassic bisulfate, which has been held in fusion a little too long. This turbidity is in no manner similar to, or suggestive of the tantalic or columbic acid separated from this melt in the absence of titanic acid. If the bisulfate melt of a mixture of tantalic or columbic acid with titanic acid be treated with a cold, 5·0 per cent solution of sulfuric acid, the solution will be completely and easily effected. If silica or stannic oxid be present these may give rise to a slight residue.

The ratio of the titanic acid to the columbic or tantalic acid will have a decided effect upon the deportment of the melt. In most of the experiments that I have made, I have held to the ratio of 6:5 for the titanic to the columbic or tantalic acid. It is evident that there is a ratio for the titanic acid to the others below which complete solution will not take place, but it is easily effected, especially with a 5·0 per cent solution of sulfuric acid, if this ratio be as high as 6:5. There is probably no ratio between these acids in a mixture which will permit of their separation on the basis of the insolubility of the tantalic and columbic acids and the solubility of the titanic acid. So far as I have been able to make out an actual separation based upon this principle is impossible, for even a small amount of titanic acid carries some tantalic acid into solution and some titanic acid is retained by the tantalic acid. These errors do not conpensate one another, so that even approximate results are difficult to obtain based upon this method, in fact, it seems a little better than an accident when usable results are obtained in this way. I am aware that this method is given, and has been since the time of Heinrich Rose. I do not know whether he suggested it or not. It is given for the separation of both tantalic and columbic acids from titanic acid in his "Handbuch der Analytischen Chemie," and I think that it has been very generally given up to very recently, if not up to the present. As I do not intend to come back to this method, I may state that I thought it possible to effect the separation of titanic acid from tantalic acid by first precipitating the tantalic acid together with a small portion of titanic acid and then fusing with potassic bisulfate to dissolve out the small amount of titanic acid. The results were very bad and the tantalic acid still contained titanic acid. The total weight of the precipitate obtained, exceeded the weight of the tantalic acid taken in the first place by 15·9 milligrams; after fusion with potassic bisulfate and proceeding in the usual manner, the precipitate, supposed to be tantalic acid, gave me 93·8 per cent of the acid taken. This precipitate was fused again with potassic bisulfate and a portion of the melt tested, after solution in water, for titanic acid by adding hydrogen peroxide, which gave a strong reaction for titanic acid.

I have no personal experience with the method based on the volatility of titanic chlorid. This method seems still to be used in laboratories in which the proper facilities are available.

A colorimetric method may be used in the estimation of Titanic Acid in the presence of Tantalic and Columbic Acid, especially the latter, provided that the amount of titanic acid be not too large. Some difficulty may present itself in obtaining a perfect solution if the ratio of tantalic to titanic acid be very high. I am not aware of any recommendation heretofore made to determine such quantities of titanic acid as may be readily and accurately estimated by Weller's method in the presence of tantalic or columbic acid, but this determination can be easily and quickly made. The procedure is very simple. If one has for example a tantalic or columbic acid in which it is desired to determine the titanic acid, whether they have been separated from a mineral in the course of an analysis or not, the mixed acids are fused with potassic bisulfate. At the conclusion of the fusion, the melt is distributed on the sides of the crucible by inclining it and turning it with the tongs while cooling. When sufficiently cool, add from 3 to 5 c.c. of sulfuric acid and heat cautiously till the whole has become liquid, when it is poured into a suitable dish. The mass will become solid but not hard; it is now dissolved in hydrogen peroxid, 3·0 per cent solution, diluted with about its own volume of water. The solution is complete and may be diluted to any desired extent. Very minute quantities of titanic acid can in this way be determined with accuracy in the presence of very large amounts of these acids. Titanic acid is not usually considered as a constituent of the Black Hills columbites, in fact, I found it a difficult task to prove its presence, but by this method there is no trouble in detecting and determining the titanic acid in one-half of a gram. In this statement, I assume that the separation of these acids has already been effected in the course of the analysis.

I had Mr. Douglass, one of my assistants, determine the titanic acid in a sample of potassic columbic oxyfluorid prepared from the Black Hills, So. Dak., columbite and he obtained 0·6 per cent; and in a columbite from Canon City, Colo., and he found 4·0 per cent. These amounts of titanic acid would probably entirely escape detection in the analysis as ordinarily made.

I have found this method of bringing tantalic and columbic acids into solution, *i. e.*, the use of hydrogen peroxid, convenient for other purposes. The form in which they go into solution is unknown to me. That the titanic acid is converted into a pertitanate is well known, but I know of no per-oxid of either tantalum or columbium, and yet the deportment of this solution indicates that a very radical change has been effected by their solution in the hydrogen peroxid. A solution, for instance, of columbic acid prepared in the manner just described, is not precipitated by ammonic hydrate when added in excess, 50 c.c. of strong ammonia water, and this solution may be boiled indefinitely, at least, I have boiled such a solution for 3½ hours and then allowed it to stand for 18 hours without obtaining any turbidity though I had dissolved one-tenth of a gram of the purest Cb_2O_5 that I have and diluted to 750 c.c. I am aware that the columbic acid used contained a small amount of titanic acid. I do not think that it amounted to more than a few hundredths of one per cent. and it cannot account for this deportment of the columbic acid solution. The fact is that the presence of any significant quantity of titanic acid would tend, as I shall show later, to carry the columbic acid out of solution.

THE EFFECTS OF ASSOCIATION SHOWN IN AN ATTEMPT TO SEPARATE COLUMBIC AND TITANIC ACIDS.

The experimental work in this line is not completed, but I can state that the deportment of these hydrogen peroxid solutions of tantalic, columbic and titanic acids are very different, so different that the suggestion of using these properties as the basis of separations is most natural and, judging from the deportment of the individual solutions, full of promise.

For instance, titanic acid is completely precipitated from such a solution on being boiled for a short time. I think that this precipitation is complete by the time that the solution fully reaches the boiling point, whereas the columbic acid is not precipitated at all from the boiling, strongly ammoniacal and dilute solution. In this case the very great difference in the deportment of the individual solutions would apparently justify the expectation that a separation of these compounds could be easily effected by simply boiling such a solution containing them. I have tried this and I am fully satisfied that a separation in this manner is impossible, for the titanic acid carries down the columbic acid. The results obtained in this effort were so very bad that I made no attempt to ascertain whether the precipitation of the titanic acid was complete or not.

It is a known fact that the association of certain compounds in a solution may affect in a profound manner the deportment of the solution. The following quotation from Crooke's "Select Methods in Chemical Analysis," presents a case in point: "Titanic acid and zirconia, which separately may be estimated with the greatest accuracy, when together present such properties that it might be said one of these two bodies had partly destroyed the individuality of the other, since the reactions they possess when separate they no longer possess when together, whilst in some cases they act quite differently. Thus it is well known that titanic acid in the state of sulfate is completely precipitated by boiling in a dilute solution; but that when in presence of zirconia there may be, according to the proportion of the two bodies, either incomplete precipitation or none at all. Moreover, the precipitated titanic acid always retains zirconia, although the greater part remains in solution with the rest of the titanium."*

In the case of the mineral strueverite, the bisulfate melt, though containing approximately 0·2 of a gram of tantalic acid, went into solution in water as though it were a melt of a titanic acid mineral, rutile for instance. I did not believe that my "black rutile" and strueverite were identical because the tantalic acid should not have gone into solution. The manuals of analytical chemistry said so and I had separated tantalic and columbic acids from their associated bases many times by dissolving them out of the bisulfate melt, by treating it with water, leaving these acids wholly undissolved, or at most only a trace of them going into solution. I had to convince myself of the identity of the two minerals named by actually separating the tantalic acid from the titanic acid before I was willing to believe that the tantalic acid was really present, and the minerals identical. Even after I had proven that the tantalic acid was present, I was inclined to think that the dissolving of the melt in water was an accident and that I might never be able to repeat the experience, in this, too, I was mistaken, for I have obtained an almost perfect solution of the bisulfate melt of a mixture of tantalic and titanic acids, also of columbic and titanic acids in both cold water and in water heated to 70 or 80° C.

It is common knowledge that a 5·0 per cent. solution of sulfuric acid dissolves a bisulfate melt of rutile in the cold to a clear, bright solution. If a bisulfate melt of columbite be treated with such an acid in the same manner, the columbic acid is left wholly undissolved and will retain the form of the melt even to its small irregularities. The same is true in the case of tantalic acid. If, however, titanic acid be present as in strueverite, the melt will go into solution completely in either cold or warm dilute acid—temperature 70 to 80° C.—and can even be heated to boiling without the separation of a precipitate.

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*Select Methods in Chemical Analysis. William Crooke, 3d Edition, 1894, p. 122.

The ratio of the acids in the mixture is known to influence the deportment of the melt or the solution. The ratio in my mixtures was 6:5, giving the titanic acid a slight preponderance. This matter of the ratio of the acids in the mixture, probably also plays an important part in the case of mixtures of tantalic and columbic acids, but this has not been an object of study. The widest ratio used in any experiments here presented was 10 to 7 for columbic to tantalic acid.

The presence of titanic acid in a hydrogen peroxid solution of columbic acid changes the results of boiling the solution so far as the retention of the columbic acid is concerned. The results obtained showed the following interesting relations. I took 120 milligrams of titanic acid and 100 milligrams of columbic acid, fused with potassic bisulfate, dissolved the melt in hydrogen peroxid, three per cent. solution, diluted to 750 c.c., added 50 c.c. of ammonia, and heated to boiling. A yellow precipitate was thrown down. The filtrate was evaporated almost to dryness. No further precipitate separated from this filtrate, though it was boiled for sometime over a free flame, till the volume was quite small. The precipitate was dissolved in hydrochloric acid and hydrogen peroxid the first time, with hydrogen peroxid and sulfuric acid in subsequent re-solutions. The solution in each instance had an intense orange-red color; the red was to my eyes very predominant. Three reprecipitations or four precipitations in all were made. This gave me 178·8 milligrams of ignited precipitate. The first filtrate was tested for titanic acid the reaction indicated only a heavy trace. In another instance, I obtained 181·9 milligrams, and in still another 176·6 milligrams.

Assuming that the whole of the titanic acid was thrown down, there should have been 120 milligrams, leaving for the columbic acid precipitated or carried down with the respective precipitates of titanic acid, 58·8, 61·9 and 56·6 milligrams. This is very nearly one-half the weight of the titanic acid, or putting it differently, the ratio by weight of the titanic to the columbic acid was as 2 to 1 or if we calculate the molecular ratio it gives us 6 to 1. As this ratio was not disturbed by the three reprecipitations, and as the ratio is essentially the same in the three experiments, it would seem that there is under some conditions definite molecular combinations formed, which act very much like elements themselves.

Though the solutions of these individual elements, titanium and columbium, in sulfuric acid and hydrogen peroxid deport themselves so differently on boiling after having been made strongly ammoniacal, no separation of the two can be effected when both are present in the same solution, because of the carrying down of the columbic acid, which in a solution by itself is not precipitated at all. Further it seems that it often may be carried down in a definite ratio to the titanic acid, 1:2, as we have just seen.

Columbic and titanic acids appear to show this effect of association to a greater extent than either of the other two pairs, tantalic and titanic acid or zirconia and titanic acid.

The gravimetric determination of titanium in the presence of columbic acid seems most difficult if not quite impossible at the present time. Small quantities of titanium can be determined colorimetrically in the hydrogen peroxid solution as above described, but in case of larger quantities the separation presents very great difficulty. Fusion by potassic bisulfate does not give good results.

SEPARATION OF TITANIC AND TANTALIC ACIDS.

The next separation attempted was of titanic and tantalic acids. These two acids react much more nearly alike when their ammoniacal hydrogen peroxid solution is boiled than the solution previously discussed. The titanic acid is practically all deposited by the time the ammoniacal hydrogen peroxid solution comes to a full boiling temperature and the correspending solution of tantalic acid begins to become turbid before a boiling temperature is reached, and is complete within ten minutes after boiling begins, while the solution of columbic acid under the same conditions is not precipitated, even on boiling for 3½ hours and standing for 18 hours additional.

The results obtained with the solution of tantalic and titanic acids together with the fact that there is an overlap in the periods of precipitation of the individual solutions of the respective acids, preclude any hope of accomplishing their separation by boiling an ammoniacal hydrogen peroxid solution in which they may be present.

For the determination of small quantities of titanic acid in the presence of much tantalic acid the method given for the determination of small quantities of this acid in the presence of much columbic acid, is available, i. e., fusion with potassic bisulfate, the subsequent addition of sulfuric acid, 3 to 5 c.c., and heating till the mass becomes liquid when it is poured into a suitable dish and diluted hydrogen peroxid solution added. The solution is perfect, easily obtained and remains clear. The color is compared with that of a standard solution.

If larger quantities of titanic acid be present, it is difficult, owing to the large dilution necessary to produce comparable colors, to make better than approximate estimations.

The statements previously made regarding the effect of the association of these two acids upon the deportment of the potassic bisulfate melt suffices to faithfully indicate the impossibility of separating these elements in this manner, though this method has been, up to the present time, almost, if not. the only one given. I have endeavored to use this method after first having removed the greater part of the titanic acid by other means, so that there was only a comparatively small amount of titanic acid present, but I did not succeed in obtaining even fair results and the tantalic acid obtained, still reacted quite strongly for titanic acid, in other words there was no separation..

I observed some years ago that the addition of ammonium fluorid to solutions change their reactions in a most remarkable manner. In some experiments though made for another purpose I observed that the addition of ammonic fluorid to a solution containing titanic chlorid and a ferric salt prevented precipitation on the addition of ammonic hydrogen carbonate, even when the solution was boiled. This experiment was repeated with a solution of titanic acid till there was no doubt but that this effect is regularly produced; on the other hand a solution of tantalic acid containing ammonic fluorid permits the precipitation of all of the tantalic acid, when boiled with ammonic hydrogen carbonate. This difference in the deportment of these elements, under the same conditions of solution, was tried as the basis of a method of separation.

The ratio of titanic to tantalic acid was 6:5, *i. e.*, 120 milligrams of titanic and 100 milligrams of tantalic acid.

The method that I adopted was to fuse with potassic bisulfate, disintegrate the melt by pulverizing it and treating it with water, the solution was often almost complete, in this case I paid no attention to this fact, but completed the solution by adding a few cubic centimeters of hydrofluoric acid, diluted 1:4. I next added ammonia enough to produce a slight, permanent precipitate. This was dissolved by adding ammonic fluorid, from 7 to 10 grams, and then from 5 to 8 grams of ammonic hydrogen carbonate. One has to guard against loss due to effervescence. The solution is now strongly alkaline and is entirely clear, but it may become turbid in a short time, due to the separation of tantalic acid—to retard this a few cubic centimeters of hydrogen peroxid, 5 to 10 c.c., were added and the whole heated to boiling. The solution now measured from 150 to 200 c.c., which, while still boiling, was poured into 300 c.c. of a boiling 3 to 3½ per cent. solution of ammonic carbonate. The boiling was continued for 25 to 30 minutes after the solution began to become turbid. The hydrogen peroxid added, delays this point, simetimes as much as 15 minutes. The precipitate has a tendency to run through the filter. It is necessary to repeat the precipitation. This is done by transferring the precipitate with the filter to a plantinum dish, adding dilute hydrofluoric acid and heating gently until all has gone into solution, after filtering and thoroughly washing the filter paper, ammonia is added till a permanent precipitate appears, which is taken into solution by a little ammonic fluorid, 5 to 7 grams, a little less hydrogen peroxid than before, 5 c.c. is usually sufficient, and ammonic carbonates as before and boiled.

One can judge pretty well in regard to the advisability of repeating the precipitation a third time by the amount of precipitate produced in the filtrate on the addition of a large excess of ammonia. If a considerable precipitate is formed, it indicates that much titanic acid was carried down with the tantalic acid in the preceding precipitation and further repetition is advisable.

While this method leaves much to be desired, it actually effects an approximate separation. The results obtained in the last four determinations of tantalic acid were 98·5, 99·0, 98·3 and 100·8 per cent. of the acid taken.

I tried fusing with potassic hydric fluorid instead of potassic hydric sulfate, my results were very much too low, two out of three times. I obtained in three trials 91·6, 93·6 and 99·8 per cent. of the tantalic acid used. It is very possible that I volatilized some of the tantalic fluorid. It requires considerable care in making the fusion to avoid this loss.

So far as my observation goes, it indicates that a single precipitation gives results ranging from 10 to 16 per cent. too high, therefore, the necessity of repeating the precipitation.

SEPARATION OF TANTALIC AND COLUMBIC ACIDS.

The method of Marignac, based on the difference in the solubility of the potassic tantalic fluorid and the potassic columbic oxyfluorid in dilute hydrofluoric acid remains, I think, the only gravimetric method for the separation of these acids. Fairly good results can be obtained, provided one has patience and a good magnifier with which to examine the residue of potassic tantalic fluorid for crystals of the more soluble potassic columbic salt. This washing is a delicate operation and according to my experience the results are often too far from the facts to justify implicit confidence in them.

This method has been modified by Meimrberg and Winzer in which they use a saturated solution of potassic chlorid to throw the potassic tantalic salt out of solution.*

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*Zeit. F. angewandle Chem. 26—Aufsatz, 157-8.

I have never worked the method of estimating the columbic acid in the presence of tantalic acid by reducing it and titrating with a permanganate solution, so I know no more about this method than the procedure given in the literature. The method is based on the fact that a sulfuric acid solution of tantalic and columbic acids to which 2·0 per cent. of succinic acid has been added may be diluted without the separation of the acids and the columbic acid therein reduced by hydrogen and estimated by titration with permanganate.

I have made an endeavor to find a method of separating these two acids which are found, so good as always, associated with one another in the columbates and tantalates occurring as minerals.

The basis of the method which I shall present is the difference in the deportment of their double fluorids in a solution made strongly alkaline by the addition of ammonic hydric carbonate, I attemtped to use the vitrious ammonic sesquicarbonate, but I did not get the same results as when I used the acid carbonate. So, without further effort to find out the cause for the difference, I adopted the acid carbonate.

The difference in their deportment is, that the tantalic acid comes down more easily than the columbic acid. For instance, if a solution of these acids in hydrofluoric acid be neutralized with ammonia or even enough of it be added to produce a slight permanent precipitate and then ammonic fluorid in excess, the precipitate will go into solution on being gently warmed. If this solution be cooled and rendered alkaline by ammonic hydric carbonate and allowed to stand, the tantalic acid soon begins to separate and comes down completely in from 12 to 16 hours, if one has not added too much ammonic fluorid. There is, however, an overlap in the precipitation of the two acids, namely, some columbic acid will come down in this time, 12 to 16 hours, even in the cold. This reaction then does not give a separation in the cold.

If to a solution of columbic acid in hydrofluoric acid 2 grams of ammonic fluorid be added and then enough ammonic carbonate to make the solution strongly alkaline to litmus paper it may be heated on a water bath kept at 70° C. for an hour without the appearance of any turbidity, whereas if a similar solution of tantalic acid be treated in the same manner the whole of the tantalic acid is thrown down in less than 45 minutes. These statements apply to solutions of the respective acids. The difficulties presenting themselves arise; 1st, from the effects of their association in the solution; 2nd, from the fact that the solutions vary in their deportment for reasons that are not clear, or are very sensitive to conditions not easily controlled, and, 3rd, that the difference in the time necessary to complete the one precipitation and to bring about the beginning of the other is so small that irregularities in the action of different solutions may cause a mixed precipitate. It is best to continue the heating till some columbic acid is precipitate (one can soon learn to judge of this not only by the time, but also by the color and character of the precipitate) and repeat the operation.

I took 450·6 milligrams tantalic acid and 301·9 milligrams of columbic acid. Fused with bisulfate and dissolved the precipitated acids in hydrofluoric acid, neutralized, added 4 grams of ammonic fluorid, and acid ammonic carbonate to strongly alkaline reaction and heated on a water bath for 45 minutes. Temperature of bath 70° C., of solution in dish 63° C., a single precipitation gave 478·0 milligrams of tantalic acid or 106·08 per cent. The recovery of tantalic acid effected in ten consecutive experiments were 106·08, 106·2, 103·45, 98·4, 97·5, 98·0, 105·5, 106·7, 100·0 and 103·8. These range from 97·5 to 106·7 per cent. of the tantalic acid taken. While these results are not as close as they should be, they serve to show that very fair approximations to the real amount of tantalic acid, when it is associated with columbic acid, can be obtained by this method, which is comparatively easy and as independent of the judgment of the operator as most other quantitative methods.

The Separation of Titanic Acid From Zirconia.

There are several methods of determining these oxids when present in the same solution. The following are methods given for this separation. Messrs. G. Street and B. Franz say that titanic acid, in the presence of zirconia, is precipitated from solutions containing dilute sulfuric and acetic acids by boiling with steam for 8 or 10 hours. This precipitate is said to be free from zirconia. Dr. G. H. Bailey precipitates the zirconia from solutions containing both titanic acid and this oxid by a strong hydrogen peroxid solution (36 per cent.) F. Pisani reduces the titanic acid to the sesquioxid and precipitates the zirconia by means of potassium sulfate. Pisani in another method reduces the titanic acid and then estimates it volumetrically, using potassic permanganate as the oxydant. Hillebrand precipitates the zirconia as a phosphate from an acid solution containing hydrogen peroxid. The preceding methods are given in modern works dealing with analytical methods. Dittrich and Pohl weigh the oxids together, fuse with bisulfate and determine the titanic acid colorimetrically, using Weller's Method.* Dittrich and Freund separate these oxids by precipitating the zirconia from a neutral solution of their nitrates as a zirconic salicylate.†

I have found the following method easy, rapid and accurate. It is based upon the fact that ammonic fluorid dissolves the freshly precipitated oxids readily and that the titanic acid is completely precipitated by an excess of ammonia, whereas the zirconia remains in solution. No excess of ammonia or continued boiling effects any precipitation of the zirconia. The presence of ammonic carbonate is in no way objectionable and may be added, in fact, I add it because it favorably affects the physical properties of the precipitate, and the whole may be transferred to a glass or porcelain recepticle if convenient and boiled.

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*Zeit. Anorg. Chem. Vol. 43, 1904, p. 236.
†Zeit. Anorg. Chem. Vol. 56, 1907-1908, p. 344-345.

The method is carried out as follows: The acid solution containing the oxids is neutralized with ammonia, a slight excess does not matter, ammonic fluorid is added till the precipitate formed on the addition of ammonia has gone into solution—a moderate excess of ammonic fluorid is advisable. Some ammonic carbonate may be added, but it is not necessary and the titanic acid is thrown down by the addition of an excess of ammonia to the boiling hot solution; continue the boiling for about one minute. The precipitation is complete and the precipitate filters easily.

If a bisulfate fusion has been made and the titanic acid precipitated from the solution of the melt, it will be necessary to dissolve and reprecipitate it, or the two oxids may be precipitated by ammonia and the precipitate dissolved in dilute hydrofluoric acid. It is well to heat the precipitate for a moment over the blast lamp before weighing.

The best method that I have found for the determination of the zirconia is to evaporate the ammoniacal filtrates to dryness, add a little more sulfuric acid than is judged necessary to convert the ammonic salts into acid sulfates and heat till the mass is thoroughly fused, and all of the fluorin expelled. The mass is then easily soluble in water and the zirconia is precipitated by ammonia. The results obtained are entirely satisfactory.

The titanic acid solution taken contained 103·8 milligrams—four consecutive separations gave 104·0, 104·1, 104·0 and 104·0 milligrams. The recovery of the zirconia is quite as satisfactory as that of the titanic acid. A few results may serve to confirm this statement. Taken 162·9 milligrams recovered 163·1 and 163·6 milligrams.

THE SEPARATION OF ZIRCONIA FROM COLUMBIC ACID.

It appears that the method just described ought to effect the separation of zirconia from columbic acid, especially as we have previously seen that boiling the solution of columbic acid, to which the proper amounts of ammonic fluorid and ammonic hydric carbonate have been added, throws down the columbic acid almost completely and that the addition of ammonia to such a solution will not precipitate the zirconia. The difference in the deportment of the two substances is so great that it promises a convenient method for the separation of zirconia from columbic and also from tantalic acid.

The following procedure was adopted to test the correctness or falsity of this inference. Potassic columbic oxyfluorid was dissolved in water with the aid of a little dilute hydrofluoric acid and a solution of zirconic chlorid added. The columbic salt taken was equal to 0·3333 gram of columbic acid, and the zirconia added was a little less than one-third of this amount. Ammonic fluorid, 3 grams, was added to the solution and heat applied till the solution was clear; after partial cooling, ammonic hydric carbonate was added in excess. If much hydrofluoric acid has been used it would be advisable to make the solution nearly neutral before adding the carbonate. The strongly alkaline solution remains clear till heated to boiling, when the columbic acid begins to come down. After boiling for a few minutes, 8 to 10 minutes, the vessel is removed from the lamp and a large excess of ammonia is added and the solution allowed to stand till cold, or nearly so, when the precipitate is filtered off. The filtrate is clear and contains almost all of the zirconia. The precipitate with the filter is treated with hydrofluoric acid in a platinum dish when it goes into solution very readily. The columbic acid is precipitated from the filtered solution as before. This reprecipitation is quite necessary. The united filtrates are evaporated to dryness, or nearly so, a sufficient quantity of concentrated sulfuric acid added to convert the remaining ammonic salts into the acid sulfate with some excess of sulfuric acid. The fluorin is then expelled by heating the mass over a free flame. The ammoni bisulfate dissolves the zirconia readily to a clear melt, which after cooling is dissolved in water and the zirconia precipitated by the addition of ammonia. The zirconie hydrate should be dissolved in hydrochloric acid and reprecipitated.

The first attempts gave me for the zirconia recovered 106·12 and 105·45 per cent. and the last one 103·75 per cent. of the zirconia taken.

In trying out this method, I have chosen columbic acid for the reason that it is more difficultly precipitated by boiling the solution of fluorids with ammonic hydric carbonate than the tantalic acid and it seems probable that we can effect the separation of zirconia from tantalic acid by this method more easily than we can separate the columbic acid, besides the columbic acid seems to be more easily affected in its deportment by the presence of other elements than the tantalic compounds. It appears as though the difficulty of separating titanic acid and columbic acid is to be attributed to this tendency on the part of columbic acid more than to the similar properties of titanic acid.

Two reactions, i.e., the fact that columbic acid is not precipitated from its solution containing hydrogen peroxid by ammonia, even on boiling, while zirconia is precipitated from such a solution as a hydrated peroxid, would seem to promise a means of separating these two substances, but this is not the case. I prepared a solution of these substances in hydrochloric acid and hydrogen peroxid and precipitated the zirconia by the addition of ammonia. A precipitate formed immediately. It was very voluminous, gelatinous and filtered very slowly. The washed and ignited precipitate weighed 184·0 milligrams instead of 101·2 milligrams, the amount of zirconia added. In this case, the zirconia carried down four-fifths of its own weight of columbic acid.

I wish to acknowledge my indebtedness to Prof. Brown, of Butler College for a review of the literature of zirconia and to Dr. R. M. Ishman for a review of literature pertaining to the methods of separation of this of elements from an another.

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NOTES ON RARE MINERAL OCCURRENCES.

By Richard C. Hills.

(Read at a meeting of the Society, December 2, 1916.)

Galena With Octahedral Cleavage.

About three years ago, while encamped on the La Plata River, Colorado, the writer received from Mr. Wm. T. Barnett several pieces of ore containing a mineral resembling galena, which he stated he had obtained on the north side of Bedrock Creek, near timber line and on property belonging to Mr. Cal. Brown. The creek referred to joins the La Plata River from the west a short distance south of La Plata City.

According to Mr. Barnett the mineral is not confined to a vein but occurs in bunches irregularly distributed through what is evidently a metamorphosed sedimentary rock, probably assignable to the "La Plata formation" of Dr. Cross.

A blowpipe test made at the time indicated that the mineral in question was very probably galena, but of the rare kind characterized by octahedral instead of cubic cleavage. Subsequent laboratory investigation confirmed this view.

Dana* cites four localities, one being in the United States, where galena of this kind has been found, viz.:

Lancaster County, Pennsylvania	G. = 7·63	
Habach, Salsburg	G. = 7·50	Bi_2S_3 1·97
Glacier Leschant, Mt. Blanc	G. = 7·61	Bi_2S_3 1·00
Nordmark, Sweden	G. = 7·508	Bi_2S_3 0·91

Dana notes that "in these cases the usual cubic cleavage is readily obtained after heating to 200° or 300°." He adds,

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*A System of Mineralogy, edition of 1892, page 49.

"it has been suggested that the peculiarity of cleavage may be connected with the bismuth usually present."

The octahedral cleavage of the La Plata mineral is perfect—as much so as the cleavage of fluorite. The character of the gangue varies considerably, being in places highly silicious, in others highly calcareous but always with more or less disseminated chloritic material. By crushing and vanning, a fairly clean sample was finally obtained, part of which was dried, finely powdered and subjected to analysis. After correcting for 1·81 insoluble sandy residue, the following results were obtained:

Pb	82·06		
Bi	1·78	= Bi_2S_3 2·19	= 3·10
Sb	0·65	= Sb_2S_3 0·91	
Fe	0·58		
Zn	0·36		
S	13·65		
$CaCO_3$	0·41	Calculated from CaO—0·23	
MgO	trace		
Ag	0·02	In the dry way	
Au	trace		
Less at 105° C.	0·05		
	99·56		

The lead was determined as sulphate by evaporating the original solution with sulphuric acid, diluting and washing with water acidulated with the same acid; finally, the precipitate was well washed with alcohol, dried at 105° C. and weighed on a tared filter. The sulphate was then dissolved as chloride, the filter washed with hot water and subsequently dried, ignited and weighed to determine the insoluble residue. The separated bismuth, dissolved as nitrate, was evaporated to small bulk, transferred to a platinum crucible, evaporated to dryness with the addition of a little ammonium carbonate and ignited and weighed as trioxide. The small quantity of antimony was weighed in the metallic state after precipitation from the chloride solution by zinc in a platinum crucible. Copper, arsenic and tellurium, though of common occurrence in the district, could not be detected in the portion qualitatively examined.

A small sample of the mineral, well cleaned under a lens, gave G. 7·50.

An effort was made to develop the ordinary cubic cleavage of galena by heating. The simple method adopted consisted in supporting a porcelain crucible by a platinum triangle over a small bunsen flame and lowering the crucible at intervals, little by little, until a pellet of test lead reached the softening point (325° C.). The lead was then removed and a fragment of the mineral the size of a small bean substituted. After 45 minutes exposure, the cooled fragment was crushed by pressure, but the octahedral cleavage was as perfect as before heating. A similar test on a second fragment gave a like result. It is possible that if, as others have suggested, the Bi_2S_3 molecule is capable of changing the cleavage of galena the Sb_2S_3 molecule may produce the same effect, especially since the two trisulphides are isomorphous in crystallization. While the percentages of these substances may, and very probably do, vary more or less in different specimens, the aggregate amount of the two (in this case 3·10) may be high enough to cause the persistence of the octahedral cleavage even when the mineral is heated above 300°.

GOLD IN LIMONITE.

The Little Annie Mine at Summitville, Colorado, which was worked in the early eighties, afforded, in the oxidized zone of the upper levels, many bunches of limonite exceedingly rich in gold. Several of the rich specimens then taken out, like those here exhibited, have fortunately, been preserved and a brief examination will convince anyone of the truth of the statement that much of this ore when beaten up in a mortar yielded nuggets of gold up to several ounces in weight.

The bulk of the gold, however, is disseminated in grains through the limonite, indicating contemporaneous deposition. Presumably, the iron sulphates resulting from the relatively deep-seated oxidation of pyrite were the solvents of the gold, which was translocated and deposited a second time, with a comparatively small portion of the iron, in the form of a secondary enriched deposit. It would be mere speculation on the strength of this instance alone to conclude that large nuggets result from such secondary enrichment. But we have in Colorado at least one other instance of the kind. The well-known crystallized gold of Breckenridge district occurs associated with limonite, usually to an extent that necessitates the use of an acid when freeing large specimens from the adhering limonite. A glance at the Breckenridge gold of the superb Campion display in the City Park Museum will show quite large nuggets that have evidently resulted from secondary deposition. Hence, it may be said that secondary enrichment favors the formation of nuggets of gold.

Gold With Barite.

Another interesting occurrence from the same district is an association of gold with barite, very rich specimens of which are here exhibited. At first glance the gold appears to be included in the mass of the barite, as would be the case if the two were of contemporaneous deposition; but a careful examination with the aid of a lens reveals the fact that the gold was deposited after the barite and in conjunction with limonite. In fact, the gold follows the limonite absolutely, not only in the spaces between the barite plates but in the multitude of irregular capillary cross fractures, in places the limonite and gold being in nearly equal proportions. This is likewise an instance of secondary enrichment. Most of the ore from the old Aztec Mine consisted of auriferous barite, the character of which was not always apparent, though revealed by crushing and vanning.

Gold With Enargite.

A third noteworthy specimen from the old Summitville mines, shows gold in microscopic crystals, agglomerated into spongy lumps, occupying small drusy cavities in a highly silicified granite-porphyry rich in enargite; the latter being a common mineral in the sulphide zone of the district where it was occasionally found pseudomorphous after orthoclase (Carlsbad twins), recalling the cassiterite pseudomorphs of Cornwall. The matrix is, apparently opaque white quartz, but a close inspection shows the presence of the transparent quartz phenocrysts of the unaltered igneous rock into which the matrix graduates.

In all the specimens examined at the time of the discovery of this ore in the lower level of the Little Annie Mine, the gold was found to be confined to spongy lumps, or pellets, like in the specimen exhibited—there was no visible disseminated gold. Hence, it is doubtful if the deposition took place in the ordinary way. There is, however, a possibility that such an occurrence may result from the removal of the mercury of a natural amalgam in which the gold is always in fine crystals. This calls to mind the fact that pellets of gold amalgam, the size of peas or larger, were found by the writer in small cavities in the quartz of the Gold and Silver Chief vein, on Cornett Creek above Telluride, in 1879.

GOLD IN CALCITE.

One of the most noteworthy specimens in the Colorado Natural History Museum collection of minerals, is one from Marshall Basin, San Miguel County, Colorado, which exhibits calcite, very rich in free gold, filling a large drusy cavity in quartz. The gold is disseminated in grains, abundantly and very evenly, throughout the mass of the calcite, while there is no visible tract of gold in the surrounding quartz. The calcite has a distinct yellowish tint, which may be due to an admixture of iron carbonate, as indicated by the amount of iron precipitated on addition of ammonia in excess to a solution of the mineral. By the aid of a lens, films of iron oxide can generally be seen as a coating partly covering the surface of the gold filaments, or in association with them. The conditions suggest the contemporaneous deposition of the calcite and gold from an iron bearing solution.

NATIVE SILVER IN SELENITE.

The specimen exhibited showing this rare association is the smallest and most inferior of three beautiful individuals belonging to the Colorado Museum of Natural History at City Park. These specimens came from the Potosi Mine about 25 miles from the City of Chihuahua, Mexico, and were donated by the late Mr. Denis Sullivan in conjunction with a large quantity of other valuable material from the same mine.

The silver is crystallized in arborescent forms partly embedded in large, clear crystals of selenite, though lying mostly on the outside and never penetrating to a greater depth than 5 millimetres. It is as though the selenite crystals grew to quite large size before the silver began to deposit. That then for some time the two were deposited contemporaneously. Finally, the deposition of calcium sulphate ceased while the deposition of silver in crystals continued for an additional period of time.

From the perfection of the crystals of both selenite and silver they were evidently formed in one of the numerous beautiful grottos or caverns characteristic of the Potosi Mine.

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A DENVER MADE SPINTHARISCOPE.

By RICHARD C. HILLS.

(Read at a meeting of the Society, December 2, 1916.)

In preparing the large explanatory cards that accompany the exhibit of radio-active minerals, in the Colorado Museum of Natural History, the writer encountered the difficulty of making the statements clear without recourse, either to detailed drawings, not always satisfactory, or to special apparatus constructed on a working scale. The Spinthariscope here shown results from the first attempt to construct, here in Denver, such simple devices as would serve to illustrate the points involved.*

There is nothing new in the design which is essentially the same as suggested by Makower and Geiger.†

In respect to manipulation there are a few points that are thought to be new, as will appear in the sequel.

It has been accurately determined that Radium in equilibrium with its alpha-ray products emits $13 \cdot 6 \times 10^{10}$ (136,000,000,000) alpha-ray particles (helium atoms) per second or, that 1 milligram of Radium emits 136,000,000 helium atoms per second. These atoms are projected in straight lines equally in all directions and each atom will produce a visible scintillation on striking the surface of a screen of phosphorescent zinc sulphide. The "Scintillation Method" of counting the number of atoms emitted in a given time is based on the two facts just cited.

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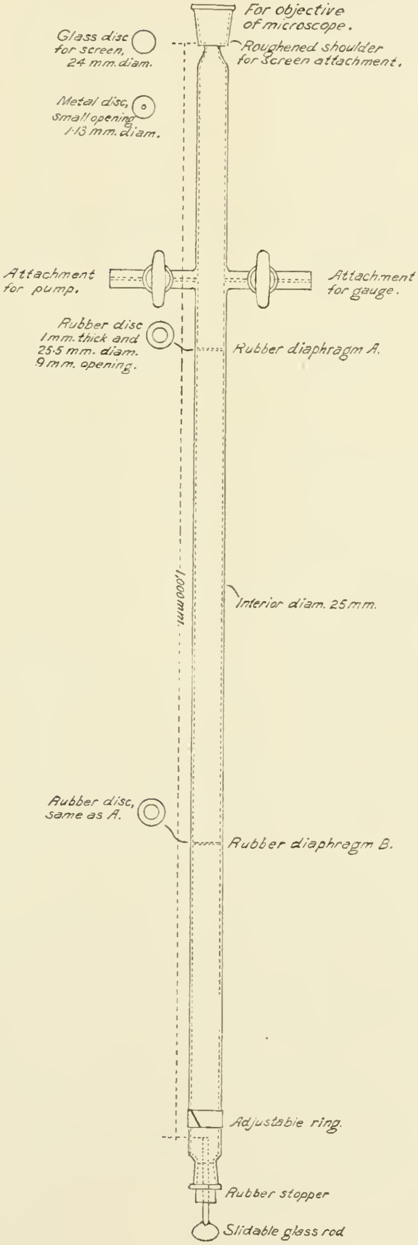
*The instrument was made from a drawing furnished the Denver Fire Clay Company, of Denver, Colorado.

†Practical Measurements in Radio Activity, p. 117.

If an active preparation be placed at the center of an exhausted hollow sphere of, say, 1,000 millimetres radius and the inner surface of the sphere be subdivided into spaces of one square millimetre area, each space will, on an average, be bombarded by the same number of atoms in the same period of time and if the number striking one of these spaces during that period can be determined this number multiplied by the number of spaces will represent the total number of atoms projected from the source during that period of time. Such is the principle involved in this method of measurement. In practice, a glass tube of suitable diameter, having an available length equal to the radius of the sphere and being provided at one extremity with a zinc sulphide screen equal in area to one of the spaces, is used for the purpose of observation.

It is essential that such a tube (spinthariscope) be accurately adjustable as to the length between the active preparation at one end and the screen at the other; that the screen end be adapted to receive the objective of a low-power microscope having a magnification of from 40 to 60 diameters; that the other end be adapted to receive a tight-fitting rubber stopper perforated for the reception of a slidable glass rod carrying the active preparation; that diaphragms be introduced to prevent the reflection of scattered particles from the sides of the tube into the screen; finally, that provision be made for the attachment of a continuously operating exhaust pump and vacuum gauge since the atoms will not travel but a short distance except in a vacuum.

The screen used must be carefully prepared and the interstitial spaces reduced as much as possible, otherwise atoms will pass through these spaces without scintillating. For this reason the percentage efficiency of the screen must be determined by means of an active preparation of known value. To simplify subsequent calculations it is best to have the exposed screen surface of definite area, say, 1 square millimetre. This can be accomplished by carefully reaming out a small hole in a thin metal disc until the diameter equals 1·13 millimetres when measured under the microscope by a stage micrometer.


For objective of microscope.
Glass disc for screen, 24 mm. diam.
Roughened shoulder for screen attachment.
Metal disc, small opening 1·13 mm. diam.
Attachment for pump.
Attachment for gauge.
Rubber disc 1 mm. thick and 25·5 mm. diam. 9 mm. opening.
Rubber diaphragm A.
1000 mm.
Interior diam. 25 mm.
Rubber disc, same as A.
Rubber diaphragm B.
Adjustable ring.
Rubber stopper
Slidable glass rod

WORKING SPINTHARISCOPE TUBE—FOR ACTIVITIES NOT ABOVE 10% OF RADIUM ELEMENT.

The tube can be supported in any suitable way that will allow of accurate adjustment of the objective of the microscope.

This disc can be cemented by means of Canada balsam to the screen side of a glass disc previously coated thinly with phosphorescent zinc sulphide and the two then cemented down tightly, with the screen surface inside, to the circular shoulder provided for that purpose.

The preparation to be investigated, preferably in the form of sulphate, should be placed, as a mere film not over one hundredth of a millimetre thick, on the small, flat end of the slidable glass rod. A disc of very thin mica somewhat smaller than the rod is then placed on the preparation and held down while thick, Canada balsam in zylol is applied around the edges and far enough over the disc so that a window of about 1 millimetre in diameter is left exposed.

The mica (muscovite) must be as thin as possible, a thickness of 0·06 millimetres being sufficient to entirely prevent the passage of the alpha rays. A fairly reliable test in this respect is the tint between crossed nicols, which should be a very pale lavender-gray of the first order. This test may be confirmed by observing the mount in a dark room through a pocket spinthariscope. The object of the mica is to prevent the escape of emanation into the tube and the formation of the active deposit some of which might reach the screen.

When finished the mount is set aside for a month to recover its equilibrium ratio.

When this condition is reached a distance of 1,000 millimetres is measured off from the screen to the brass ring at the opposite end. The mount is then adjusted until the preparation coincides with the edges of the ring. The tube is now exhausted to about 5 millimetres of mercury. All the observations are made in a dark room and after the eyes become accustomed to the darkness. To center the eye with respect to the field of the microscope, a thin brass ring about 2 centimetres high is fitted over the occular so that during the observations the eye is pressed well down to the ring which must be perforated to prevent moisture condensing on the glass and obscuring the vision.

The counting is best done with the aid of an ordinary office dictaphone the trumpet of which is conveniently curved so that with the eye on the microscope, the scintillations can be called out and recorded on the revolving cylinder of the dictaphone. At any subsequent time the device can be made to repeat the numbers distinctly at the same rate they were received and in the same time. By this means a perfect record can be retained even to the time between successive scintillations.

The observations being completed, the following calculations will indicate the total number of scintillations, or helium atoms emitted by the preparation.

Suppose that during successive periods of time, aggregating 40 minutes, 1·198 scintillations were counted, or an average of 29·95 per minute. The percentage efficiency of the screen was found to be 92·2, which increases the corrected number of scintillations to 32·48 per minute. The total number of scintillations given off at the source per second is expressed by the equation $Q = \frac{4\pi r^2 N}{60}$ in which r is the length of the tube between the screen and the preparation, N the number of scintillations observed per minute for 1 square millimetre area, and Q the total number given off at the source. By substituting the actual figures in the above equation it becomes

$$\frac{4 \times 3{\cdot}14159 \times 1{,}000{,}000 \times 32{\cdot}48}{60} = 6{,}802{,}589 = Q =$$

the total number of scintillations per second emitted from the source. Since 1 milligram of Radium element in equilibrium emits 136,000,000 helium atoms per second and the preparation under examination emits 6,802,589 per second, the quantity of Radium element contained in the latter can be calculated by simple proportion, thus:

$$136{,}000{,}000 : 6{,}802{,}589 :: 1{,}000 : 50+$$

The numbers in the second member are given in thousandths of a milligram, therefore, the Radium element in the preparation amounts to 1/20 of a milligram for 1 milligram of the substance.

While material of comparatively low activity can be tested by a spinthariscope of this size, the higher activities require a tube of greater diameter and length. Investigations of pure Radium salts will require the use of a tube from 12 to 15 feet in length. In other words, the activity of the preparation will determine the size of the apparatus.

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THE CIVIC DUTIES AND OPPORTUNITIES OF THE ENGINEER.

HOWARD C. PARMELEE

(President's Address, Annual Meeting, December 6, 1916.)

One of the fundamentals in advertising is that if you say a thing often enough, you will not only convince all who hear you, but ultimately you will believe it yourself. It is on some such principle as this that I propose to discuss a subject that has been the theme for many presidential addresses during the year, hoping always that if the world is told often enough of the need for engineers in civil and political life, the people will be convinced and engineers themselves will finally believe it.

Human experience has shown clearly that there are compensations for many incidents which in themselves seem wholly disastrous and without recompense; and so it is that out of the admitted cataclysm of war which has engulfed the world has come a definite demand for engineers, a keener appreciation of their service, and a belated recognition of their need in business and government. I have reason to believe that this recognition is a world-wide, as well as a voluntary tribute, and that it offers the engineer an advantage which he must grasp if he would retain it. Had he the tradition or the training of the lawyer, he would not only accept this position of eminence from those who are willing to accord it, but would exercise his gift of speech to persuade the remainder that no mistake would be made in committing to his care the conduct of the world's affairs. But our engineer has been so unused to the limelight that he is likely to shrink from the public gaze and retire modestly to his laboratory or works. Being the lineal descendant of the artisan, and having long been accepted in the public mind as a glorified mechanic, he will be apt to retire all too readily to the background. He needs, as never before, the support and encouragement of the professional society to give him that solidarity and community of interest which will enable him to stamp his influence on the affairs of the world.

I think we may justly claim to have established a profession of engineering, although some may contend that we still have merely a "procession of engineers." By definition, a profession is that calling or occupation which one professes to understand, a vocation in which a professed knowledge of some department of science or learning is used by its practical application to the affairs of others. Formerly, theology, law and medicine were specifically known as "the professions," but I think we may fairly claim to have established engineering on a more solid and scientific basis than any of them. Theology has been almost wholly speculative, the law technical, and medicine empirical. Each has been irrational, and all have gained prestige by claiming it.

On the score of service to humanity also, I think that engineering may fairly claim professional standing. The achievements of engineers in all parts of the globe are accepted evidence of their ability, but tradition causes us to halt at this recognition, as though the only field in which an engineer could accomplish anything, was in the design and construction of some great work. Such things are well enough in themselves, but in the meantime the affairs of business and government are left to men of limited training and narrow vision, and those things which are fundamental in our national life are suffering from the lack of vital direction, which engineers could give.

We have sometimes heard it said of an individual that "he may be a good engineer, but he is no business man." I resent the implied difference. An engineer is a manager, one who carries a project to conclusion in an efficient manner. I might consent to such a statement as, "he is a good mathematician, but no business man," or "he is a good surveyor, or assayer, but no business man,"but I must contend that if he is a good engineer, he will be a business man. The war has brought out few more striking incidents of management than the direction of the commission for relief in Belgium by Herbert C. Hoover, an engineer of technical achievement in his profession. This commission has handled $227,000,000 worth of supplies, keeping alive a population of 9,000,000 and operating with an overhead expense of but three-quarters of one per cent of the gross cost. Such is engineering efficiency in business, organized in an emergency, and administered under constant stress. What might such ability accomplish applied under the normal conditions of business, with ample time for planning and execution?

The engineer is entitled to recognition not only as a producer but as a director of policy. Hitherto he has accepted the responsibilities of operation and production, while the control of the enterprise was in the hands of a banker or merchant. Under these conditions, the work of the engineer might be ever so efficient, and yet the enterprise might fail through ignorant management in the executive or selling department. Complete control on the part of the engineer might avoid such a catastrophy and relieve himself, as well as his associates, of inevitable embarassment. I think that engineers are coming to demand this form of control, being willing to accept responsibility if they are also given authority. Any form of dual control, with the responsibility still resting on the engineer, is intolerable.

The modern engineer can bring to bear on business all of the general essentials to success. Organization is his forte and management his specialty. With him the handling of men and supplies is a matter of scientific procedure and the keeping of accounts and unit costs a prime necessity. Plainly the ability of such a man should not be confined wholly to the details of operation or production; but should be requisitioned on the board of directors, or executive committee.

Perhaps it is more in the realm of government of civic and political activity that the engineer is yet to receive his highest recognition. Certainly it is in this field that he must strive most earnestly for a hearing and for a chance to apply his methods. The strongest traditions are against him and he is handicapped by a lack of familiarity or intimate relation with political organizations. There is no question, however, that his ability, viewpoint, and methods are sadly needed. Accustomed to considering propositions on their merit, and having an abhorrence of waste and inefficiency, he would be less likely to yield to political expediency in matters of great consequence. I doubt if pork barrels would appeal to engineers having ethical standards as high as our statesmen would probably assume for themselves. The latter may be good business men in this case, but certainly not good engineers.

There is probably a growing demand for fewer lawyers and more engineers in our civic and political life. There has never been a time in our national history when technical and engineering advice was more needed on matters affecting our industrial growth and welfare. The intricacies of the dyestuff tariff, for example, could not be reckoned with intelligently by lawyers and merchants, nor can the revision of the mining law be sanely undertaken by men who merely own stock in mining companies.

Recently the subject of scientific management received consideration at the hands of Congress in such a manner as to elicit caustic criticism and ridicule from laymen as well as engineers. The House passed a bill forbidding time and motion studies on government employees, and prohibiting the adoption of any scheme of remuneration involving bonuses or premiums for excellent work. This was a sad and disgusting spectacle, considering the truly remarkable achievements of scientific management and organization in various industrial lines. It is typical of the manner in which Congress plays politics with matters that should receive intelligent and broad-minded treatment. Instead of welcoming the possibility of placing government business on a basis of efficiency, Congress yielded to political pressure, threw a sop to a prejudiced faction and held departmental work to the dead level of mediocrity. At a time when private business was being forced to study efficiency and the whole country realized the necessity of such action, and when one of the candidates for presidency was talking about "America Efficient," Congress exposed its own inefficiency by putting a spoke in the wheel of progress. Popular impression prevails that governmental departments are not on an efficient basis and engineers can render a service to the country by expressing that opinion in a manner so forceful as to show Congress the light.

In matters more vital to the mining and metallurgical industry, Congress acted with even less discretion. The recent proposed tax on copper, for the purpose of raising revenue, was a case in point showing how illogically and superficially a profound subject may be approached. Apparently sensing a popular impression that copper was highly profitable constituent of war munitions, and without first establishing a broad fundamental economic basis for raising revenue in an equitable manner, Congress singled out copper for taxation and gave itself over to class legislation of the wildest sort. Such unfair taxation as was proposed in the case of copper can be charged only to a profound ignorance of conditions I have no doubt that instances might be multiplied to prove political inadequacy in dealing with technical affairs and showing the need of engineering advice.

One of the finest examples of national service on the part of engineers and technically trained men is the Naval Consulting Board. Through its numerous committees it has attacked fundamental problems of research, gathered technical data on the country's resources, and stimulated interest in the nation's welfare. Another instance is the Public Relations Committee of the American Electrochemical Society. This is composed of its past presidents and is organized for the purpose of advising with government officials and expressing an interest in various public problems. Through this medium the electrochemists and electrometallurgists exert their influence on such national problems as the development of hydroelectric power and the fixation of atmospheric nitrogen.

To what extent this voluntary public service can be carried depends wholly on the results obtained and the reception which it is accorded. Ultimately it should arouse a demand for that kind of service and result in bringing more experienced engineers into public life. The good example thus set should be followed in state and municipal governments also. Our legislatures and city councils are no less in need of engineering advice than is Congress, while state and municipal affairs generally are subject to abuse and need correction. Town planning and management are engineering problems of first rank, wholly beyond the scope of politics and above the grasp of politicians. Numerous departments of government depend upon technical direction for their successful operation and for the economic handling of funds. In such things engineers should not only take an active part, but should advise those in authority.

Some attention also may be profitably turned to the daily press of this country. There is no more potent force in spreading information or creating public opinion. In technical and engineering matters, however, it is woefully ignorant and in need of sound advice. If we could encourage the editors of our dailies to consult with engineers and scientists on pertinent topics before publishing their dispatches or writing their editorials, we would prevent the dissemination of a lot of things that are not so and avoid the ridicule which inevitably is heaped upon newspaper science.

I admit there are other things wrong with our newspapers, which engineers cannot correct, and I am not recommending that engineers become editors of our dailies, for I doubt if we would have much in the way of newspapers under such direction; but I do think it is possible to encourage a closer co-operation between newspapers and engineering or scientific societies so that the public would get more exact information on technical matters.

Some of the most important civic problems which the engineer will have to solve in the future are more human in their aspect and concern the conservation and distribution of labor. Miss Frances E. Kellor, assistant to the chairman of the Immigration Committee in the Chamber of Commerce in the United States of America, believes that this is one of the great industrial problems of the day and that it will be solved only by the application of engineering methods. Writing on the subject of Engineers and the New Nationalism, in the Engineering Record, she states that the stabilizing of the labor supply is of the utmost importance. "The average labor turnover in the United States is about 200 per cent in the industries upon which America must depend in time of war; in other words, for every 100 men kept at work, 300 are employed. This is a sheer waste of men due to lack of combination in the regularizing of industry and employment of men. In the past we have relied upon the economist and the professor to tell us about unemployment, irregularity of work, vocational education, and similar industrial questions. The laboratory for study has been the employment agency and the lodging house and the remedy—a law. In the future it will be the engineer who studies the problem in the plant and the remedy will be the adoption of measures within the industry itself, which will make laws as unnecessary as they are useless to deal with such questions. America has today no system for distributing labor; we are trying to get it by establishing a federal bureau of employment. It will succeed just in proportion as business men use it; otherwise, we are building our distribution system without plans or specification, a base here and a girder there, over which only an aeroplane could take us. When the engineer grapples with the problem of distribution he will give us a structure on which men can and will travel to work best suited to their needs."

If I have outlined a more or less ideal state of affairs, I do not wish to be understood as anticipating a sudden or immediate realization of my hopes. There are, nevertheless, many indications that the public duties of engineers are being appreciated by the profession and that the faithful discharge of these duties will open the way to new opportunities. Finally, with a public conscience quickened by the failure of political government to give us a conservative and efficient management of public affairs, a demand will arise for engineering methods, if not for engineers.

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A CONTRIBUTION TO THE HYDROLOGY OF THE SAN LUIS VALLEY, COLORADO.

By Wm. P. Headden

The hydrology of the San Luis Valley, which lies in the southern part of Colorado, between the Sangre de Cristo and Culebra ranges on the east and the San Juan country on the west, presents some interesting questions. The valley itself embraces an area of from 4,000 to 5,000 square miles surrounded by mountains, except at the southern end, and across which extends a sheet of lava and through which the Rio Grande has cut its present outlet, the Embudo Canyon. This sheet of lava constituted at one time the southern shore of the San Luis Lake, the bed of which forms the present valley. The rainfall varies from 6 to 15 inches in different parts of the valley which constitutes a rather arid climate. The altitude varies from 7,525 to practically 8,000 feet. The mountains about the valley are high, 14,000 feet, especially on the east side with a steep watershed, while on the west side the watershed is more gentle, but the mountains attain a considerable height. There is no water entering the valley except that collected on these watersheds. It would seem that the water entering the valley should be of uniformly good quality which, so far as I know, is actually the case.

In similar territories throughout semiarid countries the so-called alkalis are apt to occur abundantly. This valley is no exception, on the contrary, such salts are very abundant, often covering square miles with a white efflorescence. These white, efflorescent salts consist of a mixture of sulfates, principally sodic sulfate with some sodic chlorid. This is the general character of the alkalis, but other types may be found. The Hooper-Mosca area is now characterized by a considerable amount of the carbonate of soda.

The Rio Grande divides the valley into two sections. This river enters a little north of the middle of the western side, runs southeastwardly almost across the valley and then south to the entrance of its canyon at the State Bridge. The course of the river through the valley is about 60 miles long.

The lowest portion of the valley lies well toward the eastern side with an altitude of 7,525 feet. Del Norte, which may be taken as at the western side of the valley, lies 36 miles directly west of this point and has an altitude of 7,866 feet, which gives the surface of the valley a dip to the east of 341 feet in 36 miles. Antonito, lying 42 miles south and 15 miles west of this point, has an altitude of 7,878 feet, so that we have a fall from south to north of 353 feet in 42 miles. From these factors it would seem that the drainage should flow toward the north and east. The Rio Grande has cut its canyon through the lava sheet and thus affords an outlet for all waters that find their way into it. There is a large number of streams some of them of considerable size, which are entirely lost in the valley and never reach the Rio Grande—others may reach it in times of flood.

The volume of water that thus disappears is very considerable and an interesting question arises as to what becomes of it, whether it reappears somewhere or remains in the valley.

The Embudo Canyon, through which the Rio Grande discharges its waters, is the only visible outlet for the waters of the whole valley, therefore the discharge of the Rio Grande at Embudo becomes a matter of interest. From the State Bridge to Embudo is approximately 70 miles. There is a decided increase in the flow of the Rio Grande between these two points. There is some overground discharge into the Rio Grande within this distance, but after allowing for this there remains a very decided increase over the flow at the

State Bridge. Whether this increase is due to leakage from the valley or not, may remain a question. As an interstate question affecting the permissibility of impounding the Rio Grande waters this increased flow is of considerable interest, but the discharge at Embudo is less 4 years out of 5 than the discharge at Del Norte, near which town the Rio Grande enters the valley. The suggestive question is what becomes of the water brought into the valley by all the other water-courses discharging into it. This question does not enter into the interstate one at all, but is of the greatest economic importance to the valley. Perhaps a more general statement will be even clearer, the drainage area of the valley is approximately 8,000 square miles, sometimes given as 9,000 square miles. The drainage area of the Rio Grande above Del Norte is 1,400 square miles. The discharge of the Rio Grande at Embudo in New Mexico, more than 60 miles below the southern limit of the valley, is usually less, but sometimes more, than the discharge of the Rio Grande at Del Norte. This is the water collected on 1,400 square miles out of approximately 8,000 square miles of watershed. The precipitation undoubtedly varies in different portions of this area, but not sufficiently to justify consideration in these general statements. It seems clear that the runoff from 6,600 square miles of this watershed has no visible avenue of escape from the valley.

The only evident, invisible means of escape for these waters is evaporation. That this will take place rapidly under the conditions obtaining in the valley is certain, for the valley has an altitude of 7,500 feet, the sunshine is almost continuous, a rather strong wind is of almost daily occurrence and the temperature at midday is quite high. Under these conditions evaporation from a free water surface is rapid, according to the most reliable information at my disposal, 61 inches per annum, which may be taken as twice as much as it is from a land surface. That this is an important factor in the problem can not be questioned, for there are large areas in the valley throughout which the water-plane is within 3 feet of the surface, i. e., within the limit of the capillary movement of the water. This is not true of the whole of the valley, nor is it known of how much of the valley it is true, but if it were true of 1,000,000 acres of land it would account for at least 2,500,000 acre-feet of water or a discharge of about 3,500 second-feet into the valley, of this amount the rainfall, of about 10 inches, will account for 1,150 second-feet which is freely subjected to evaporation.

That the valley is really filled with water is indicated by the fact that it constitutes a large artesian basin. The number of wells that have been put down now amounts to 5,500 or upwards. The shallowest of these wells is said to be less than 70 feet. I personally know of a flowing well which is 77 feet deep. I have heard of one failure to find water within what is considered the limits of the artesian basin. The difference in level betweel Del Norte, where the Rio Grande may be said to enter the valley and the lowest portion of the valley, is only 341 feet. The relation of the underlying strata has not, to my knowledge, been made out. The difference of the surface at the two places may not be that of the water bearing strata. The number of flows encountered in sinking the deepest wells seems not to be obtainable—but is upwards of a score.

The source of these artesian waters is the mountain area surrounding the valley, in other words, they are the river and creek waters that have found their way into the strata of sand which alternate with clayey strata. These waters are stored in the valley and unless the discharge from the valley, together with the evaporation from its surface equals the total inflow, the valley must be filling up. We have seen that the known discharge is materially less than the known inflow, it being certainly no greater than the discharge into the valley from the drainage area of the Rio Grande, 1,400 square miles.

Some years ago I undertook to study the changes effected in the river waters by the irrigation of land forming a part of the drainage area of some of our western streams. Such a study is feasible, as fairly good sized streams may be wholly diverted either into reservoirs, or, by means of large canals, directly to the land. The waters of the Poudre, a stream with an average annual flow of about 600 second-feet, are used in these ways seven times before they are permitted to discharge into the South Platte river. The changes effected in the amount and kinds of salts held in solution are radical in character and large in amount, especially by their first application to the soil. The water of the Poudre river, for instance, taken 15 miles below its point of exit from the mountains, is found to have changed, except in times of flood, almost to its maximum degree, both in regard to the quantity and character of the salts held in solution. Within the mountain section of its course this water usually contains less than 3 grains of total solids to the imperial gallon; these 3 grains consist so good as wholly of carbonates and silicic acid held in solution. This silicic acid has wholly disappeared and the carbonates become so subordinate that they are almost wholly negligible by the time the water makes its first return to the river bed. Instead of 3 grains of total solids, we have from 100 to 150 grains to the gallon, and instead of carbonates with an excess of silicic acid, we have sulfates and chlorids with some carbonates, the sulfates being strongly predominant. In the mountain water the principal bases are lime, soda and magnesia present as carbonates, in the water taken down the stream we have the same bases as sulfates, but in very greatly increased quantities. Of lime, we have in the mountain water 0·5 to 0·6 grain to the imperial gallon; in the lower river water 14 to 19 grains. Of soda, in the mountain water 0·4 grain and in the lower river water 9 to 14 grains. In this case the river has cut its bed below the level of the country and drainage exists. In the case of Rio Grande we find a different condition, here the river has built up its bed till it is higher than the adjacent country. The result is that there is no drainage or very little into the river, and though the volume of the flow decreases from Del Norte to the State Bridge, a distance that

I have estimated at 60 miles, the increase in the fixed total solids is only 2.3 grains to the gallon, i.e., from a total of 4.2 to 6.5 grains, while the composition shows only minor changes the principal one being an increase in the amount of sulfuric acid present—which increased from 7.5 to 11.6 per cent. of the total solids. The silicic acid still remains, constituting 22.5 per cent. of the total solids. This persistency in the character of the solids held in solution is consonant with the fact that, as a rule, the river shows a loss of water between Del Norte and the State Bridge after an allowance is made for all of that taken out for irrigating purposes, and strongly indicates that none or only an insignificant quantity of water flows into it either as off-flow or drainage water.

This peculiar condition leads to the question of what may be the character of the surface- or ground-waters that might drain into the river. In regard to surface or off-flow waters there are none but such as may be furnished by heavy rains, which might be affected by the alkalis in the surface portions of the ground. These alkalis, especially in the section of the valley lying south and west of the river from which they would come, are essentially sodic sulfate with some calcic sulfate. The ground waters are richer in calcic sulfate than the effloresced alkalis and from 5 to 8 times as rich in total solids as the river water. These features of the alkalis and the ground waters further justify the view that there can be no considerable amount of either finding its way into the river water.

While there are a few springs in the valley large enough, perhaps, to constitute a factor in the water question of the valley—the McIntyre Springs, for instances, with a discharge of 20 second-feet; the Dexter Springs and others, there is none that apparently bears directly upon these questions.

These springs themselves can scarcely be supplied by surface-waters, as is usual in the case of springs, for there are no sufficient earth masses from which the flow could come. The McIntyre, Dexter and Washington Springs rise from the bed of the valley and so do the springs at the head of Spring Creek. It is probable that they come from as great or greater depths than the artesian waters of the La Jara district. These are probably not surface springs in the ordinary sense, but are simply leaks from the artesian basin. The amounts of total solids present and their composition indicate that this is the case.

If these springs really be artesian waters may their consideration throw some light on the hydrology of the valley? These waters present a very striking question, for while there is but one artesian basin, there are two very distinct artesian waters. The limits between these two classes of water is not definitely established, but for our purposes the statement that a line drawn a few, not more than five, miles north of and approximately parallel to the Rio Grande will divide this artesian basin into two parts. The southern one furnishes a colorless water carrying in no instance more than 16 grains of total solids to the imperial gallon. This water comes from a depth of 923 feet. These total solids are characterized by the presence of 50·0 per cent. of silicic acid and the presence of carbonates. The part north of this line yields an alkaline water which at a depth of 200 feet carries 22 grains of total solids in each imperial gallon and grows richer with depth till at 880 feet it carries upwards of 100 grains to the gallon. These total solids have but one characteristic, they consist essentially of sodic carbonate. Silicic acid is very subordinate about 5·0 per cent., and lime and magnesia are almost entirely absent. While the waters of the southern part are colorless, those of the northern part are mostly colored, varying from a slight yellowish brown to a full brown*. A few of the waters in this section, from shallow wells which are located near the edge of the basin, are colorless, but all that I am acquainted with are alkaline. Even the water of a well 15 feet deep, used for domestic purposes, carries 15 grains of sodic carbonate to the gallon, which is 75 per cent. of the total solids. The water developed by the large drainage ditches, is of the same character, in fact, is quite similar in character to this 15-foot well water. Another difference between the artesian waters of these two sections is the presence of hydrogen sulfid in those of the northern, while it is absent from those of the southern section.

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*Analyses of several of these brown waters are given in the American Journal of Science, Vol. XXVII, April, 1909, p. 315.

The following analyses of the total solids obtained from these waters will make the differences clearer than the preceding general statements.

	Rio Grande above Willow Creek *Per cent.*	*Artesian Well Alamosa 820 feet deep* *Per cent.*	*Brown water Mosca 750 feet deep* *Per cent.*
SiO_2	43·395	50·982	5·167
SO_3	6·096	2·926	0·196
CO_2	13·352	14·610	36·923
P_2O_5	0·229	-------	-------
Cl	0·907	0·468	0·434
CaO	19·845	3·229	0·563
MgO	3·791	-------	0·179
K_2O	2·886	1·976	0·456
Na_2O	6·759	24·087	51·766
Fe_2O_3 & Al_2O_3	0·610	0·236	0·170
Mn_3O_4	0·657	0·100	0·146
Ignition	1·685	(1·882)	4·267
	100·212	100·106	100·276
O=Cl	0·212	0·106	0·098
	100·000	100·000	100·178
Grains per imperial gallon	5·39	14·63	104·3

Such are the big features of the hydrology and drainage of the valley. Can these facts be correlated and can any rational interpretation of them be presented? The strata of this old lake formation are derived from the same source throughout, i. e., the rocks of the surrounding mountains. This signifies that the action of these strata upon their contained water should be the same throughout the valley. From the petrographic standpoint these sands consist of some quartz, but they are made up principally of fragments of eruptive and metamorphic rocks. Local deposits of a different character may serve to indicate differences in the conditions at these places, perhaps they may even denote periods when there was no rapid formation of either sand beds, or clays—but it is a question whether, in fact, there are any beds of this sort of sufficient extent to modify the characters of the underground water. I may illustrate the condition had in mind by the case of a sand met with at a depth of 350 feet in sinking a well at Hooper. This well was sunk by means of a jet of water and the sand washed out has, of course, been subjected to a violent washing. As received, it is quite free from clay and there are only a few small, worn grains of the dark colored eruptive rocks so common in the ordinary sand usually encountered. The color of this sand is a very light gray and an examination of it under an ordinary pocket lens suggest that it is not a sand at all, but a felt of small angular splinters; an examination under the microscope shows that it is not composed of sand grains in the ordinary sense, but of translucent to transparent angular fragments which under a higher power show parallel striation, perhaps ribbing is more descriptive in this case.

The composition of this material, as well as its deportment in polarized light, shows that it is really a felspar. Its composition is as follows:

Washed sand from depth of 350 feet.

	Per cent.
SiO_2	71·18
Al_2O_3	11·58
Fe_2O_3	2·41
Mn_3O_4	0·25
CaO	1·68
MgO	0·41
K_2O	4·02
Na_2O	4·05
Ignition	4·74
	100·32

While some of the ferric oxid may be present as hydrate, this is wholly insufficient to account for the 4.74 per cent of loss on ignition. The material gives off water on heating in a closed tube.

The material from a depth of 550 feet is a rather coarse sand typical of the valley, to which a pepper and salt appearance is given by the presence of a great many ostracoid shells.*

The character and origin of these special formations might be interesting to study, but they can form no factor in the larger features of the problems presented, which practically resolve themselves into two questions, i. e., what drainage has the valley and why have we these two classes of water of directly opposite character?

The drainage question is of interest in this connection only in so far as it may determine the character of the artesian water found in the different sections. We have given the discharge of water into the valley and that of the Rio Grande at Embudo, N. Mex. We know of no other outflow than that furnished by this river. In 1902 the total amount of water discharged by the Rio Grande at the State Bridge is given as 173,518 acre-feet, while the total discharge at Embudo was 282,032 acre-feet; in 1903 the discharge at the State Bridge was 642,607, and at Embudo it was 1,036,600 acre-feet—a trifle over 1½ times as much as at the State Bridge where the river enters Embudo Canyon. This excess of from 100,000 to 400,000 acre-feet of water apparently represents the drainage from the valley that finds its way into the course of the Rio Grande. We do not know how large a percentage of the drainage from the valley this volume of water represents. The important fact, however, is the strong probability of an actual drainage out of the valley established by this increase of the discharge within the 65 or 70 miles represented by the canyon. Waters from our watersheds, flowing over granites and mica schists or bowlders and sands formed by their mechanical disintegration, in short, mountain waters, have a common but distinctive character which changes very quickly on their entrance into a territory of a different character. All of the waters flowing into this valley are mountain waters. This character is scarcely changed at all by the valley strata. This is evidenced by the fact that the Rio Grande water retains this character after flowing for 60 miles through the valley. The artesian waters of the southern portion of the valley retain the characteristics of mountain water, even though a small portion of this section, as we have divided the valley, lies north of the river. The full justification for this statement is shown by the results of our analyses of a considerable number of samples of these waters. The Rio Grande water taken at the mouth of Willow Creek, which is 37 miles above Del Norte, carried 5·4 grains to the imperial gallon, at Del Norte 5·4, at Monte Vista, 14 miles further down the river, 5·9, at the State Bridge, about 100 miles below Willow Creek, 8·9 grains. The artesian well designated as Widow Smith's, carried 5·7 grains and the Washington Springs 6·6 grains to the imperial gallon. The Bucher Well, 923 feet deep, carries 15·9 grains to the imperial gallon. The composition of the total solids held in solution by these waters is more remarkable than the uniformity in their quantities, for they are of the same type and character. The increase in the total solids carried by the Rio Grande water at the State Bridge over the amount carried at Del Norte may indicate that a small amount of surface-water had found its way into the river, but at the same time it must be remembered that the total amount of water passing the State Bridge per annum is less than one-half that which passes Del Norte, or if we take it in August or September, the months within which our samples were taken, this quantity is about one-twentieth and concentration due to evaporation is not excluded. All of these waters, to which may be added those of the Dexter and McIntyre Springs, differ almost not at all from mountain waters. I have cited the fact that artesian flows in the southern section of the artesian basin are met with at very shallow depths, as shallow as 65 feet. That these waters are not becoming stronger by evaporation is quite evident from the small amount of total solids held in solution and the slight increase shown by even the deep wells. The effects of the mineralogical composition of the sands carrying these artesian waters are evidently and fortunately the same as those of the surface rocks which was to be expected from what we have said concerning the nature and origin of these sands themselves. This is really the fact, which we believe accounts for the similarity of character which we find in the river and artesian waters.

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*I am indebted to Prof. Junius Henderson, of Boulder, for the determination of the true nature of these fossils.

An examination of the discharge of the Rio Grande at Embudo reveals the fact that it is approximately equal to the discharge of this river at Del Norte, usually a little less, but some years more. In a general way there is drainage enough out of the valley to keep the water of this section of the valley quite constant in composition and character.

The waters of the northern section of the valley though originally of the same character and confined within strata, at least of similar if not identical character, present altogether different properties. The total solids held in solution are very much greater in quantity and very different in kind. While it follows that the differences found in the composition of the total solids held in solution, are due to the conditions obtaining in this section, it is evident from our preceding statements regarding the mineralogical similarity of the sand strata, and inferentially of the clays throughout the valley, that we cannot consistently attribute any of these differences to their action, nor do we wish to, for we do not believe that they have at any time played any part in producing them.

We have given the differences of level for sections of the valley from south to north and from west to east showing a difference of approximately 350, between Del Norte on the west and the San Luis Lake near the eastern side of the valley. These two places lie on the same east and west section line. This difference of surface level probably corresponds to a difference which has existed during the deposition of this whole formation. Further, the statement has been made that the Rio Grade has built its bed higher than the adjacent valley, in other words, it now runs on the fan that its current built out into what is now the valley. There are no known folds or faults in the valley, or if there are, they antedate the deposition of the Alamosa formation. This Rio Grande fan is probably the only wave in the formation dividing the valley into natural drainage areas. The one to the south has some drainage, probably sufficient to prevent further filling up of the valley, and to prevent concentration with its consequent results, so that the character of the water remains constant. This drainage is not sufficient to affect the character of the water for any considerable distance north of the fan, even though the fan be but moderate in height. The Rio Grande was probably as active a transporter of rock debris at the very beginning of the Alamosa formation as it has been since and its fan was probably as pronounced during the time of the old San Luis Lake as it is now, perhaps more so.

What the sequence of land and water areas has been within the valley can not be made out, but there must have been periods of at least marshy conditions within this northern district. I take it that this is the explanation of the brown color of these artesian waters and the significance of the fragments of wood that are occasionally washed up in putting down the wells, and the presence of gas. I assume that the drainage of this section was relatively the same as now, very poor or nil, and for the same reasons. The water, then as now, coming from the mountains surrounding this section on three sides, flowed into it. This discharge over a very long period has been approximately in balance with the evaporation so we have a concentration of these waters in this area on a comparatively large scale.

The characteristics of a mountain water are the presence of silicic acid, calcic carbonate with sodic and potassic carbonates, the latter in the ratio of 6 or 8 to 1. We find these relations, somewhat modified it is true, continuing in some of the ground-waters and shallow wells, and even in the deep artesian wells in the southern section. In the northern section this is in no measure true. Here we find the silicic acid, the calcic and potassic salts quite completely removed even in the upper artesian flows. The waters from a shallow surface well 15 feet deep, and the waters developed by drainage ditches, show similar changes, i. e., an increase in the total solids and a concentration of the sodic salts. The water of the 15-foot well alluded to, carried 21 grains to the imperial gallon, 15 grains of which were sodic carbonate. The removal of silicic acid and potassic salts by clays or other soil constituents with which their moderately concentrated solutions may come in contact is a well established fact.

The chemical differences which have been established between these two classes of waters present no contradictions to what we know to be facts. There is a question of the adequacy of the process of evaporation to account for the concentration of the water. The discharge into this section of the valley at the present time is from the best information that I can obtain, liberally estimated at 2,000 second-feet. If we take the area involved at 1,000 square miles, which is an under estimate, but it will serve, for if the facts apply to this area they will apply, in the main, to the rest. We will have, accepting data previously given, i. e., an evaporation of 61 inches annually from a free water surface and 36 inches from the soil surface, the removal of about 2,000,000 acre-feet of water by this process, which is already in excess of the estimated discharge of 2,000 second-feet into the section. This will account for a very large accumulation of residual sodic salts. This statement assumes that practically the whole of the water supply is furnished directly by rainfall, which in a general way is probably true The assumption that there is so good as no drainage out of this section is also in general terms probably correct.

An idea of the amount of soda salts which may at the present time be accumulating within this territory presents itself on the assumption that each imperial gallon of water that is evaporated represents 1 grain of sodic carbonate. The amount deposited annually on this assumption is approximately 36,000 tons. How long this has been going on we cannot tell, but that the same general physical conditions have obtained in the valley's past is suggested by the peaty water which comes from all depths down to 880 feet.

The occurrence of the mineral natron in a bed attaining a thickness of 48 inches at one point in this section is due in my opinion to this natural process. References to the possible connection between this deposit and the brown artesian waters may be found in an article on "The Brown Artesian Waters of Costilla County, Colorado, Their Relations to Certain Deposits of Natron or Soda and what they Teach" in the American Journal of Science.*

The economic, especially the agricultural effects of these conditions are very important, but their discussion scarcely belongs in this place.

RECAPITULATION.

The San Luis Valley is the bed of a former lake, which was formed by a flow of lava across its southern end. The Rio Grande eventually drained this lake by cutting the present Embudo Canyon. During the existence of the lake the Rio Grande built a fan or bar that probably extended across the lake and subsequently drifted southward. The Rio Grande at the present time flows on this fan. The Rio Grande forms the only visible outlet for the waters that flow into the valley. The water discharged at the State Bridge is materially less than the discharge of the Rio Grande at Del Norte. The discharge of the Rio Grande at Embudo, N. Mex., is approximately equal to the discharge of the Rio Grande at Del Norte.

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*American Journal of Science, Vol. XXVII, April, 1909, pp. 305-315.

This increase over the discharge at the State Bridge is probably due to drainage out of the southern section of the valley south of the old Rio Grande fan. This drainage has probably always existed and together with the aspect of the valley has prevented the formation of marsh lands or a material concentration of the waters in this part of the valley. A continuous artesian basin occupies a very large portion of the valley. The water of this artesian basin is of two classes, one having all the essential characteristics of a mountain water, the other being strongly alkaline and usually colored due to the presence of humus. The old fan of the Rio Grande separates these two classes of waters, those north of it are alkaline, those south of it have acids in excess of their bases, so for convenience, I have designated them acid waters. The drainage to the south is not sufficient to affect the area north of the fan. This division of the valley has existed in the past, there having been marshes in the northern section. The whole valley is now quite filled with water, strong artesian wells being encountered at depths of 65 to 75 feet in one portion of the valley. The northern section of the valley has never been drained thoroughly, but the discharge of water into the valley is not, and probably has not been, since the formation of the present valley bed, greater than the annual evaporation. These two factors, the inflow of water and the evaporation, have maintained in effect, an equilibrium so that a concentration of the salts held in this water has been effected. The silicic acid, calcium and potassium carbonate have been removed, leaving the soda salts, now present as carbonate, in the remaining water. There is one deposit of sodic carbonate within this area attaining a mixumum thickness of 48 inches whose origin is attributed to the evaporation of the brown artesian waters.

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THE VITALITY OF ALFALFA SEED AS AFFECTED BY AGE.

By Wm. P. Headden.

The following notes are presented without any pretense that they represent a study of the subject from the standpoint of the physiological botanist. They are the statement of tests made from time to time of seed with which I began tests over 22 years ago. I had at that time no thought of extending the observations over any number of years—this will explain the fact why no definite observations on the temperature to which these seeds have been subjected, and no notes made of the degree of moisture present in the air, etc., are given. The method of preservation differs for some of the samples, this is purely accidental. The samples of seeds were obtained from commercial sources except in the case of Number 1, which is a hand-picked sample. This was gathered from plants grown without irrigation and was quite mature at the time of gathering. Commercial seed could not be gathered with the care that I gathered this and that used was probably gathered with a mass of plants, many of which were immature and may have been left in bunches on the ground exposed to the weather to become moist with dew or wet with rain and partially decayed. There can be no doubt that these conditions obtained in the case of the screening samples, for moulds and bacterial growths developed readily in these samples under favorable conditions. It follows that the prime seed, corresponding to these screening-samples, whether I chanced to get a sample of it or not, was exposed to the same kinds of infection. Further, sample numbered 1 was gathered from thrifty, matured plants which had not been cut for hay that season and the abundance of seed was evidence that the season itself had been a favorable one. These conditions, either singly or taken collectively, have a big influence upon the vitality of the seed obtained at any given harvest. The manner of preservation, the temperature and moisture of the atmosphere to which the samples may be exposed are probably not only important but determining factors in the duration of the vitality of seeds in general, and especially of such as ordinarily have a strong vitality, as the alfalfa seed evidently has.

It has not always been considered that the alfalfa seed has a strong vitality. Loudon in his Encyclopaedia of Plants, p. 647[1], says: "The seed is paler, larger, and dearer than that of clover, it is generally imported from Holland, great care should be had to procure it plump and perfectly new, as two-years old seed does not come up well." This was printed in 1880, but it was probably written as early as 1855. But lucerne or alfalfa was a well-known plant very long before this date.

The same view is expressed in the North Carolina Bulletin No. 60, 1888[2]. The statement there made is: "The greatest care should be exercised in selecting seed. The vitality of lucerne seed is so low that seed over one year old is scarcely worth sowing. Two sprouting experiments were recently made at the North Carolina Experiment Station.

"In each experiment 100 seeds were taken. In the first case 6 seeds only sprouted, in the second 12. These seeds were brought to the station in September, 1886, and were presumably two years old."

In the Iowa Experiment Station Bulletin 88, 1906, p. 69[3], it is said of the samples: "The vitality of the alfalfa seed was very low, the average for plump seeds was 56·91 per cent. and in shrunken seeds 24·16 per cent."

The authors of this bulletin do not make a general statement that alfalfa seed has a low vitality, as the authors of the preceding quotations do, but they assert it of the samples tested.

The United States Department of Agriculture gives the average germination for good alfalfa seed as 85-90 per cent.[4] These percentages may be taken as conservative. The maximum percentage given, 90 per cent, is lower than I obtained in 5 out of 6 samples of prime seed ranging from 2 to 6 years of age. In these samples of prime seed, I got from 0-13 hard seeds in taking a hundred seeds just as they came. These hard seeds are very slow in sprouting, but in my experiments 78 per cent of them finally sprouted.

In discussing the vitality of alfalfa seed in the Colorado Experiment Station Bulletin 35, 1896[5], I made reference to the first two quotations and gave the results of 11 sprouting experiments made in duplicate as justification for my disbelief in the statements made. The source, age, and quality of the samples were given with the results of the experiments. The results were not at all in harmony with the statements made in the quotations given. It is true that good, plump, mature seed showed a better germination than second or third grade seeds, many of which were so shrunken that one would consider it improper to consider them seeds, in fact, many of them were not. In these samples moulds developed on many of these shrunken seeds in a few days, while in some other cases they became surrounded with gelatinous masses which swarmed with bacteria. The surprising thing in this connection was that second grade seed or screening of the first quality, 1 and 2 years old, showed a sufficient degree of vitality to give, using the same weight of seed, more plants to the acre than the best prime seed, and that the third grade screenings, one year old, would give 60 per cent of the plants given by the first grade seed.

The object had in mind was merely to ascertain whether seed likely to be found on the market might be valueless on account of its age and not to ascertain how long alfalfa seed might retain its vitality. It may, further, be proper to state that, in the sprouting experiments, I endeavored to obtain maximum results and continued them until the seeds either sprouted or rotted unless they were hard seeds. This explains why the experiments were continued for 14 days, though 3 days will suffice to show whether the seed is good or not.

It has already been stated that the hard seed ranged from 0-13 per hundred in the different samples; the average was 5·6 per cent. for the prime seed and 6·1 per cent. for the screenings. Seventy-eight per cent. of these hard seeds germinated within 38 days. The results obtained in 14 days are reproduced in the following table:

TABLE I.

Number	*Quality*	*Years old*	*Seeds per Pound*	*Average Germination*
1	Prime seed	2	206,837	96·00
2	Prime seed	2	228,818	92·00
3	Prime seed	2	208,021	95·50
4	Prime seed	2	....	88·00
5	Prime seed	3	....	98·50
6	Prime seed	6	....	93·00
7	1st Quality Screenings	1	259,340	66·50
8	1st Quality Screenings	2	344.123	55·50
9	1st Quality Screenings	3	266,233	79·00
10	2nd Quality Screenings	2	331,383	38·00
11	3rd Quality Screenings	1	312,385	38·50

These samples were tested again in 1900, in 1906, one sample in 1917, and all of them in 1918.

The first tests were continued for 14 days, but the subsequent tests were continued for only 4 and 6 days. For this reason the percentages of germination are not quite comparable. The following tables give the results obtained in the respective years:

TABLE II.

RESULTS OBTAINED IN 1900.

Sample	*Quality*	*Years old*	*Seeds per Pound*	*Average Germination*
1	Prime seed	6	206,837	92·00
2	Prime seed	6	228,818	80·00
3	Prime seed	6	208,821	70·00
4	Prime seed	6	....	78·00
5	Prime seed	7	....	66·00
6	Prime seed	10	....	72·00
7	1st Quality Screenings	5	259,340	53·00
8	1st Quality Screenings	6	334,123	25·00
9	1st Quality Screenings	7	266,233	42·00
10	2nd Quality Screenings	6	331,383	42·00
11	3rd Quality Screenings	5	312,385	25·00

TABLE III.

RESULTS OBTAINED IN 1906.

Sample	*Quality*	*Years old*	*Seeds per Pound*	*Average Germination*
1	Prime seed	12	206,837	92·5
2	Prime seed	12	228,818	82·0
3	Prime seed	12	208,821	74·5
4	Prime seed	12	....	73·0
5	Prime seed	13	....	66·0
6	Prime seed	16	....	63·0
7	1st Quality Screenings	11	259,340	33·0
8	1st Quality Screenings	12	334,123	16·0
9	1st Quality Screenings	13	266,233	38·0
10	2nd Quality Screenings	12	331,383	14·0
11	3rd Quality Screenings	11	312,385	14·0

Sample 1 is seed that I gathered in Weld County in 1894 from volunteer, uncared-for plants growing on ground too high to be irrigated from any of the ditches. The seeds were large, as the number per pound indicates. It was fully ripe when gathered, but had not suffered from long exposure to the weather. I have for these reasons considered this as my best sample. It has been kept in my work room in a glass stoppered bottle, sealed with paraffin. I cannot give the range of temperature to which it has been subjected, but the room has been kept at 80 degrees F. for considerable periods. It has very seldom been below 32 degrees F. The seed has a somewhat rancid odor. In 1906 four tests, not included in the last table, were made. These tests were continued for five days and gave results varying from 92 to 98 per cent. with an average of 94·25 per cent. It is evident that this 12-year-old seed was equal to a very good sample of fresh seed. Four tests of this sample, which were continued for three days, were made in 1917 with results varying from 95 to 98 per cent. with an average of 96 per cent. This seed gave the same percentage of germination at 22½ years of age as at 2 years. This is, probably, nothing more than a coincidence, but the vitality of this seed cannot be said to have abated in this time. Recently I made six trials of it, but I continued them for a little less than three days as I had no further purpose in view than to satisfy my own curiosity. The results are interesting enough to justify their detailed statement.

TABLE IV.

PRIME SEED, TWENTY-THREE AND ONE-HALF YEARS OLD.

Trial	*Seed Taken*	*Not Sprouted*	*Hard Seed*	*Sprouted in 2½ days*
1	100	2	6	92
2	100	6	4	90
3	100	7	3	90
4	100	4	3	93
5	100	5	2	93
6	100	3	3	94

The last two sets of trials may possibly indicate that this seed sprouts a little more promptly than it did when fresh. We found, however, in 1896, that we obtained from 80·5 to 93 per cent. of the total germination in the first three days.

These results suggested the desirability of repeating the tests with the samples of 1896, of which I fortunately have all except sample 2, which has been used up in former trials. It is for this reason that this number is left blank in the following table which gives the average results of two trials:

TABLE V.

RESULTS OBTAINED IN 1918.

Sample	*Quality*	*Years old*	*Seeds per Pound*	*Average Germination*
1	Prime seed	23½	206,837	90·5
2	————	----	-----------	------
3	Prime seed	23½	208,821	51·0
4	Prime seed	23½	-----------	62·5
5	Prime seed	23½	-----------	44·0
6	Prime seed.....At least	27½	-----------	46·0
7	1st Quality Screenings	22½	259,340	24·0
8	1st Quality Screenings	23½	334,123	17·0
9	1st Quality Screenings	24½	266,233	11·5
10	2nd Quality Screenings	23½	331,383	27·0
11	3rd Quality Screenings	22½	312,385	16·5

A comparison of Tables III and V shows that samples 10 and 11 germinated as freely or more so at the age of 23 or 24 years than they did at 11 or 12 years. These samples in this latter trial did not develop the gelatinous form of rotting elsewhere referred to. While in 1906 they did, and sample 9 developed it quite badly in 1918. I think that this explains the apparent anomaly. I am so fully satisfied that this is the case that I doubt whether these samples planted in the usual manner would produce any plants, for the gelatinous masses produced in the rotting of the seeds kill strong and apparently healthy sprouts that come in contact with them.

No attention has been paid to the color or size of the seeds taken for these trials, but all seeds were taken just as they were counted out. In the case of the screenings it would have been impossible to distinguish seeds under either of these classifications, but it might have been done in the samples of prime seed. There were brown seeds and also small seeds in most of these samples. Sample 6 in particular is rich in brown seeds, which is no matter for surprise, as the sample was kept from 1891-1896 in a showcase exposed to the light. The color of the seed in sample 1 is not uniform, some of the seeds are brownish and some are greenish-yellow, but the brownish ones are not brown like those of sample 6. Those of sample 1 may have changed in the 23½ years that they have been kept, but they have not lost any of their vitality and I do not think that they have changed much in color. I have seen fresh seed that contained brown seeds. It may be, in fact, it is claimed, that such seeds are not desirable. In the Experiment Station Record, Vol. XXXI, p. 436, we read: "Results of testing seed for growers, dealers and farmers in the State led to the conclusion 'that the presence of either brown or green seeds lessen the value of (alfalfa) seed from a commercial standpoint. Our many tests of western grown alfalfa seed have shown that in practically all samples there is quite a large percentage of hard seeds that will not germinate in 28 days. Dry-farm alfalfa seed contains a larger percentage of hard seeds.' "[7]

Sample 1 is really a dry-land alfalfa seed. We have indicated its color and given the percentage of hard seeds. The statements just quoted ought to apply to it, but the application is doubtful. I do not know the origin of sample 6. Samples 4, 5, 7, 8, 9, 10 and 11 are Colorado seed and even the samples of prime seed are very far from being free from brown seeds. Whether this is due to age or was originally a characteristic of the seed, I do not know. The light brown seeds in sample 1 make up about two-thirds of the sample. The other samples of prime seeds are rather badly discolored. The screenings are, as the name suggests, immature, shriveled seeds which vary exceedingly but agree in being strongly discolored and shrunken. In the second and third grade screenings one would scarcely think that 10 per cent. of the seeds when fresh would germinate.

There is no question but that the seed produced in different years will differ considerably in vitality. I cannot take this into consideration for I do not know the conditions or even the year with certainty in which some of my samples were produced. My oldest sample, for instance, was obtained by

PLATE 1

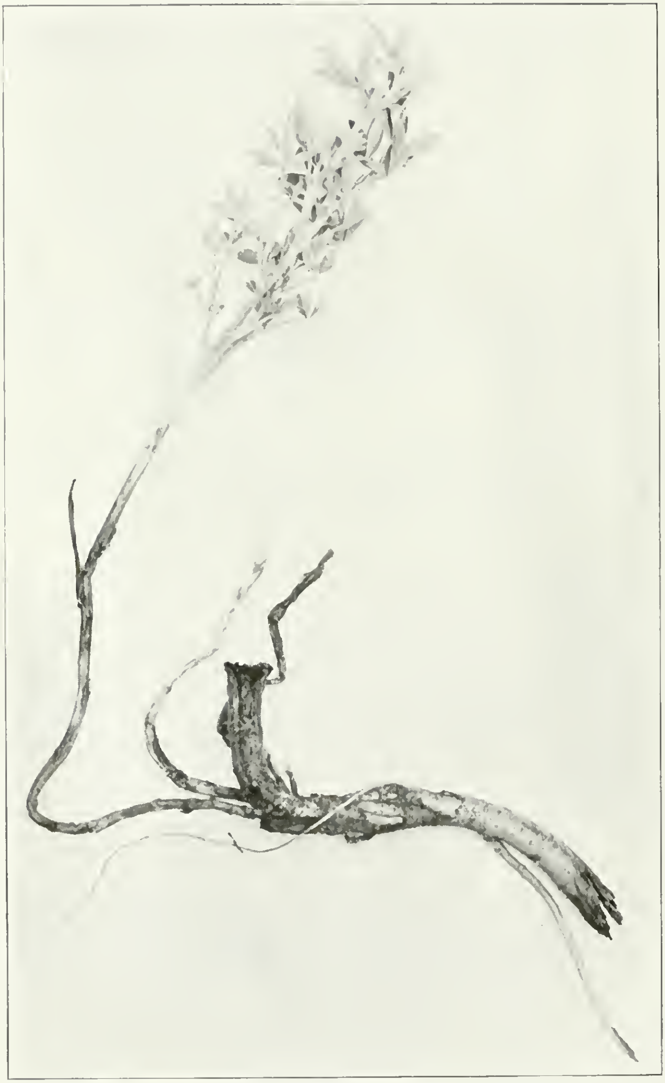

Plate II

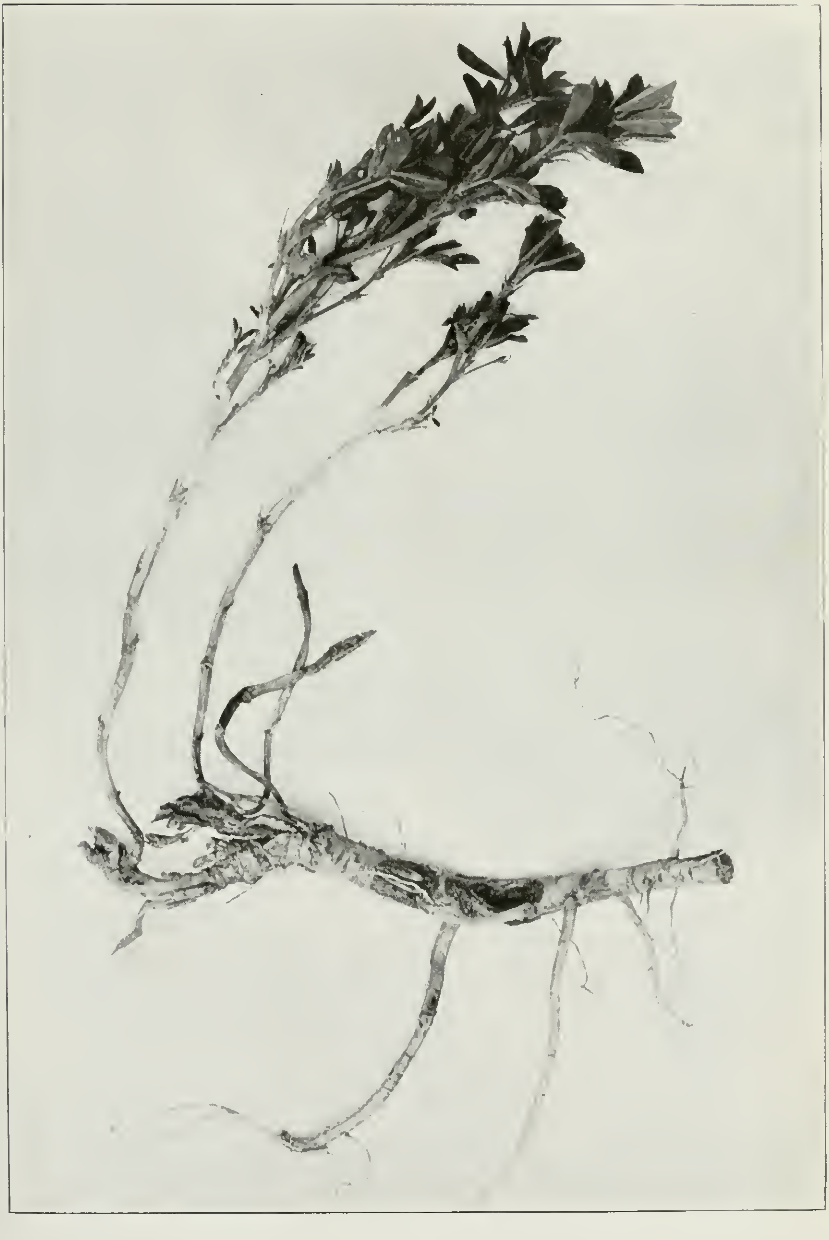

PLATE III

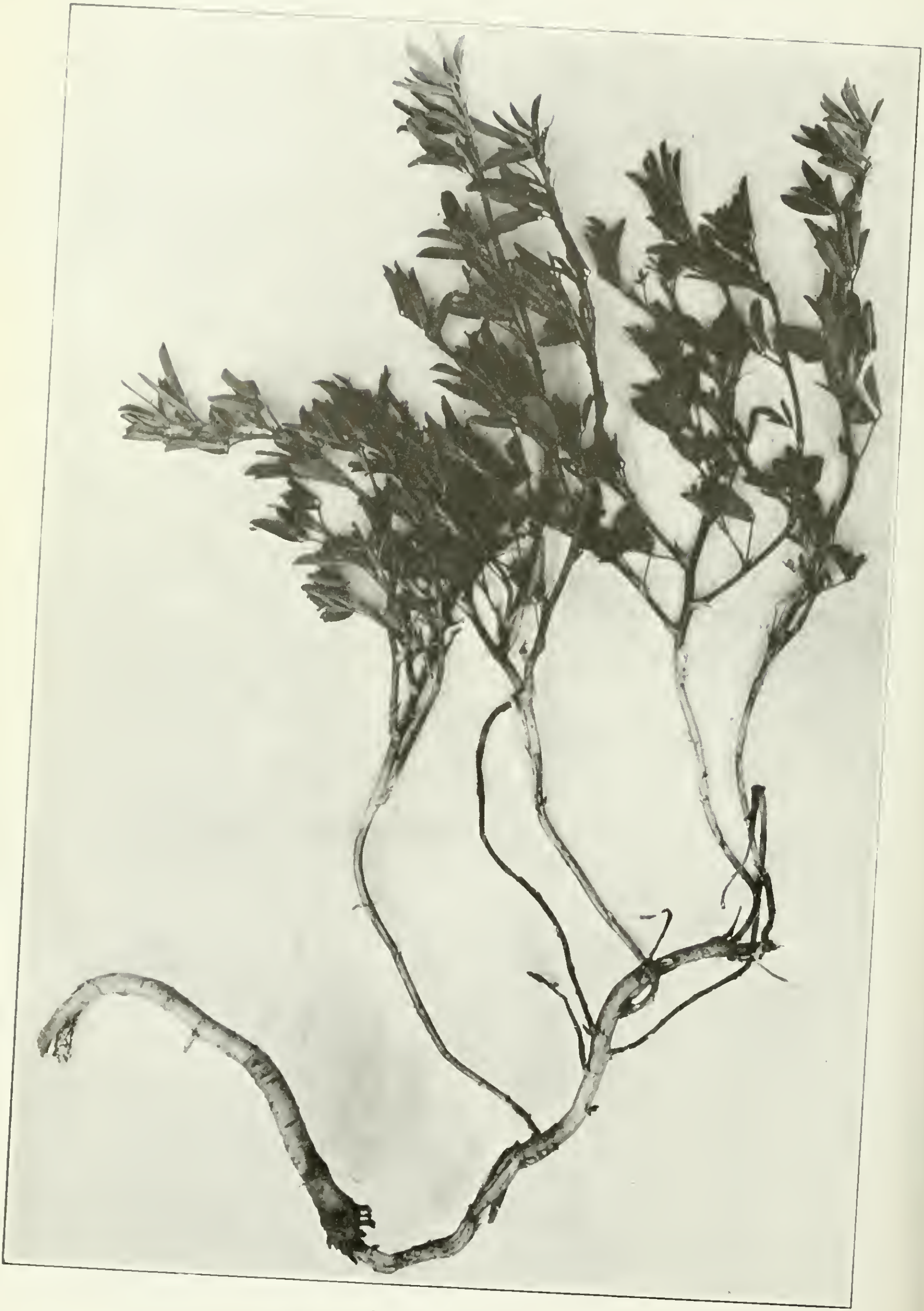

Plate IV

Prof. Crandall in 1891 from the U. S. Department of Agriculture and the seed was furnished by Peter Henderson and Company of New York. This history is good enough so far as it goes, but it is of so good as no value in this connection. The same is true of all of the samples except sample 1. While I cannot give the origin and history of the other nine samples, eight of them were probably grown in the Arkansas Valley in Colorado.

Mention was made in Bulletin 110[8] of this Station of the fact that some of the samples, especially the screenings, rotted rather badly. The figures given to illustrate this were 59 and 66 per cent. for the second and third quality of screenings. This tendency in the immature seeds to rot could scarcely be absent as soon as the seeds were placed under conditions favorable to the development of moulds and putrefactive bacteria with which they were infected at the time they were threshed and which were checked only by the drying of the seeds. In these cases the treatment of alfalfa from the time it was cut till it was threshed may have much to do with the vitality of the seed. Further, I know nothing about the manner in which it was preserved before it came into my hands. It has been shown by J. W. T. Duvel in Bulletin 58, Bureau of Plant Industry,[9] that the conditions of temperature and moisture under which seed may be stored are very important factors in determining the persistency or decay of their vitality. Even since the samples came into my hands they have received no special care. Samples 4 and 5, for instance, have been preserved for the 22 years that they have been in my possession, in paper envelopes placed in a pasteboard box and kept in a basement sample room.

The conditions under which the seed plants have grown are supposed to have a great deal of influence upon the character of the seed. As we have already seen dry-land seed is stated to contain more hard seeds than other; our samples are not sufficient in number to justify conclusions in this regard, but so far as they go they suggest some other factor, for instance my dry-land sample shows fewer seeds of this sort than several of the other samples which in all probability were grown with irrigation. Another question is in regard to the influence of altitude upon the character of the seeds produced. I have only one sample of seed which may be justly considered as a high altitude seed. This was produced in the San Luis Valley at an altitude of 7500 feet. The sample of seed is at the present time 11½ years old. It has been preserved in a tightly closed vial kept in my workroom. No test of its germinating power was made when it was fresh. Two trials were made of it in connection with this work. The trials were continued for four days; the results were 78 and 83 per cent., average 80·5, with 6 hard seeds in each case. The vitality of this seed has abated scarcely at all in 11½ years and it is still very satisfactory.

Experiments on the vitality of alfalfa seeds were made in 1880 or 1881 by Italio Giglioli[10] and again about 13 years later. These experiments were made with various gases, liquids and solutions. Abstracts of the original articles are contained in Nature, Vol. 25, 1882, pp. 328-329,[11] and Vol. 52, 1895, pp. 544-545[12]. These experiments show the persistence of vitality in alfalfa seeds under extraordinary conditions, but do not determine it for seeds kept under ordinary atmospheric conditions. In two experiments he shows that, kept in the air, alfalfa seed which at the age of two years showed 83 per cent, at something over three years showed only 50 per cent as viable. The gases experimented with were oxygen, hydrogen, nitrogen, sulfuretted and arseniuretted hydrogen, carbon nonoxid and dioxid, nitrous and nitric oxid, ammonia, and sulfur dioxid. The liquids used were: Methyl, ethyl and amyl alcohol, chloroform, carbon tetrachlorid, ethyl iodid, glycerin, benzol, nitrobenzol and aniline. The solutions used were copper sulfate, arsenious acid, potassic sulfid, ammonic sulfid and potassic cyanid in glycerine, camphor and phenol in alcohol, phenol in ether and in aniline. The results were in themselves interesting, but have little bearing on the question presented in these notes.

It is evident that good, sound, clean alfalfa seed, kept under fair, not ideal, conditions will retain its vitality for 23½ years without any perceptible abatement. Further, that good, commercial seed, preserved under rather disadvantageous conditions retains a fair degree of vitality, 46 per cent., for 27½ years. Further, that very inferior seed, third quality screenings, kept under rather indifferent conditions still contained 16·5 per cent. of viable seeds when 22½ years old.

I am indebted to Dr. H. G. MacMilian for information regarding the literature on this subject.

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11. Nature, Vol. 25, 1881, pp. 328-329.
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THE VITALITY OF ALFALFA ROOTS.

By H. G. MacMillan.

During the spring of 1918 volunteer alfalfa was common and abundant in the tilled fields of northern Colorado. The preceding winter had been mild and the ground was frozen only at the surface. Fields which had been fall plowed in 1916 or spring plowed in 1917, and planted to row crop during 1917 came up abundantly with alfalfa in 1918. This phenomenon caused only passing interest, and was generally regarded as due to the mildness of the winter.

While investigating one of these fields some interesting discoveries were made. This field had been spring plowed in 1917 and planted with potatoes. It was heavily cultivated during the following summer, and in the fall after the crop was removed, it was plowed deep again for spring planting in 1918. Early in the spring the field was harrowed and floated. On May 21 a picture was taken showing the field free from all growth except a fair scattered stand of alfalfa. This is illustrated by Plate I.

Some plants were dug at random to ascertain the condition of the roots. A plant was found which had grown from an adventitious bud on an old root. The root was minus a crown, and both ends of it were well shattered and decayed. No growth had occurred during the summer of 1917. In the spring of 1918 the bud sent out three shoots, two of which died, the third reaching the surface and putting forth leaves. Rootlets were also sent out from this bud. So far as is known such vitality has not been recorded in roots of this kind. This plant is shown in Plate II.

Many other plants were found where the new growth had arisen from the old crown, as is shown in Plate III. This plate shows the new roots emerging from the vascular ring of the old root and old lateral roots. The leafy branches are shooting out from the old crown. Plate IV shows a further growth in this direction, in that the old crown sent out a shoot which grew in the summer of 1917. In the spring of 1918 this shoot sent out new leafy shoots from adventitious buds.

The plants illustrated in Plates III and IV show the usual methods of secondary growth from alfalfa roots. Plate II illustrates a plant of exceptional vitality and strength, for it had no opportunity for growth for one year; it was subject to mechanical injury from farm machinery, and to the rots and decays which attack non-growing vegetable matter in the soil. It retained its vitality and after a year sent forth shoots, two of which died; the third emerged safely and under normal conditions would have established the plant. Such vitality in the world's greatest forage crop is certainly a valuable asset.

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VOL. XI, pp: 253-268.

AN INVESTIGATION OF THE STRESSES IN THE TRANVERSE BENT FOR STEEL MILL BUILDINGS

By C. S. Sperry

The tranverse bent as commonly used in shop or mill buildings consists of a roof truss supported on two columns and braced by diagonal kneebraces joining the truss to the columns near its ends. The structure is not statically determinate, and is a two-hinged, or fixed, arch according as the columns are assumed free to turn, or fixed, at the bases. Owing to the combination of columns, which take stress by bending, with a framed truss the determination of the true stresses in this structure is a matter of some difficulty and it is customary for designers to use approximate methods for obtaining the stresses. These methods have been found by actual experience to give safe design* so that their use has become well established. The aim of this paper is not to urge the replacement of the approximate methods of obtaining stresses by an exact one, but to investigate the accuracy of the stresses obtained by the various approximate solutions so that designers may be guided in the choice of a solution and the reservations with which it should be applied. Finally, improvements to the approximate solutions will be suggested should this appear desirable.

To determine the true stresses in an indeterminate structure the actual size of the members must be given. Two bents with Fink roof trusses were selected. The first, designated as Bent One, is an intermediate tranverse bent in the machine shop building of the Hunt Engineering Co., Kansas City, Missouri. The stresses from the shop drawings show that the roof truss was designed by using an equivalent uniform load of about 40 lbs. per square foot of horizontal projection of roof truss, acting vertically and concentrated at the upper panel points of the truss. No attempt was made to compute wind stresses. The columns and kneebraces were apparently made up according to the judgment of the designer. The use of an equivalent uniform load gives good results in the design of roof trusses supported on walls. The results of this paper will show whether the practice is advisable for braced bents. The span of the bent was 67 ft., pitch of roof one-quarter, height of columns 20 ft., truss spacing 16 ft. This bent had a monitor over the panel at each side of the peak of the roof which was omitted in working out stresses. The stresses from the shop drawings are given in Table I.

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*"Wind Stresses in Steel Mill Buildings," by R. Fleming, "Engineering News," Vol. 73, No. 5. Feb. 4, 1915.

Bent Two is an intermediate tranverse bent span 60 ft., pitch one-third, column height 24 ft., spacing 16 ft. It was designed according to the specifications in Ketchum's "Steel Mill Buildings," 3d edition, Appendix I, for columns hinged at base. The dead load was taken at 10 lbs. per square foot of horizontal projection. The stresses used in design are the same as those given in Table II under the headings of Dead Load, and Wind Load, Ketchum's Method, under Approximate Stresses.

Comparison of stresses being the object, a discussion of external loads as given in Fleming's article already cited, is unnecessary, provided a reasonable standard is used. For Bent One the dead load was figured from the shop drawings and amounted to 13·13 lbs. per square foot of horizontal projection. For Bent Two 10 lbs. per square foot was taken for dead load. In all solutions, true and approximate, the dead load was assumed uniformly distributed and concentrated at the upper panel points of the roof truss acting vertically. The wind load was assumed to be 30 lbs. per sq. ft. of vertical projection on the roof resolved normal to it by Duchemin's formula, and 20 lbs. per sq. ft. on the side of the building. The wind load on the roof was concentrated at the upper panel points. On the side the wind load was concentrated in the various prescribed ways for the approximate solutions. For the exact solution the wind on the side was assumed to act as a uniform load along the column. The moment diagram due to wind loads concentrated at girts equally spaced on the column will be closely that of a uniform load and the calculations were much simplified. Concentration of the loads as in the approximate solutions seemed insufficiently exact. The loads used are those specified by Ketchum. Fleming recommends smaller loads, but those used are undoubtedly reasonable. The wind loads were applied on the windward side of the building only, no suction effect being considered. On this question Fleming and Ketchum agree.

The columns of the bents were assumed either entirely free to turn at their bases or entirely fixed. Fleming rightly says that the true state of affairs at the column bases is between the two. The conditions assumed, however, represent the extremes of what may occur and if the errors of the approximate solutions are determined for these two cases, the errors of any other solution which assumes partial fixedness at column bases will lie between, provided it follows the same procedure as the approximate solutions with which it is compared.

With respect to internal conditions in the bent, center lines of members were assumed to intersect in all cases which is approximately correct. Further, the roof trusses were supposed pin-connected at the joints with members free to turn. The members of the roof truss were also supposed free to turn at their junctions with the columns. The last assumptions amount to neglecting secondary stresses. The approximate solutions use these same assumptions and determine the primary stresses only in a bent, and in order to find out their errors it was only necessary to find the correct primary stresses in the bent with a sufficient degree of exactness. Secondary stresses will not affect the primary stresses more than a slight amount, and so far as the secondary stresses themselves are concerned, they should be more than allowed for by the unit stresses used in design. Temperature stresses were not considered. Crane load stresses are a factor in some bents, but neither of those selected were designed for such loads.

The results of the stress calculations for the two bents are given complete in Tables I, II, III and IV. In the tables the + sign indicates compressive stress, the — sign tensile stress. But one approximate solution for dead load stress is in current use in which the stresses are computed as if the roof truss were simply supported at the ends. The roof truss is assumed to be so rigid that the stress in the kneebraces is zero. The approximate dead load stresses are thus the same for columns hinged or fixed. A number of approximate solutions for wind load stresses are possible, but only two appeared to be of sufficient importance to merit investigation. They are the solutions for wind stresses in tranverse bents given by Ketchum in his "Steel Mill Buildings," 3d edition, Chap. XI, which are those most in use at the present time, and the solutions given by Hutchinson in Johnson, Bryan and Turneaure's "Modern Framed Structures," 3d edition, Chapter XXIX. Hutchinson's solutions have been replaced by Ketchum's in the 9th edition of "Modern Framed Structures."

The tranverse bent with hinged columns is a two-hinged arch. Under dead load the downward deflection of the roof truss puts compression in the kneebraces and bending stress in the columns, causing two equal horizontal reactions at the column bases. The part taken by the columns and kneebraces in carrying the load causes the stresses in the roof truss to be less than if it were only simply supported. The errors of the approximate dead load stresses are given in Tables I and II for the two bents. The deflections of the roof trusses under dead load are shown in Figures 1 and 2. Bent One is less rigid than Bent Two and shows greater errors in its approximate stresses. The main roof truss members have stresses up to +75 per cent in error for Bent One and up to +40 per cent in error for Bent Two. The compression in the kneebraces is respectively 3776 lbs. and 1540 lbs.

For wind loads the bent with columns hinged has vertical reactions determinate, and the sum of the horizontal reactions equal to the horizontal component of the wind load, but the division of the shear between the columns is not equal and these reactions are unknown. The reason for this is that the columns, though the same in size, do not deflect symmetrically and hence take horizontal shear in unequal amounts. The diagrams of Figures 1 and 2 show this. The columns do not deflect symmetrically, first, because of the unequal distortion of the roof truss, and second, because the loads on the columns are not the same to windward and leeward. The crux of any approximate solution for wind stresses in a hinged bent thus lies in the manner of dividing the horizontal shear between the horizontal column reactions. Both Ketchum and Hutchinson concentrate the wind load on the windward column at top of column, foot of kneebrace, and base. Hutchinson then subtracts the concentration at base of column from the total horizontal wind load and places one-half of the remainder as a net horizontal reaction at the base of each column, the wind concentration at base of windward column being dropped. Ketchum divides the gross horizontal wind load in two, places one part at base of leeward column, and the other at base of windward column, subtracting the wind concentration at this point to get the net reaction. His method gives greater horizontal shear in the leeward than in the windward column. A table of the approximate and true reactions follows:

HORIZONTAL WIND LOAD REACTIONS. COLUMNS HINGED.

		Ketchum	*Hutchinson*	*True*
Bent One	Windward	4000	5100	
	Leeward	6200	5100	5695
Bent Two	Windward	5270	6550	
	Leeward	7830	6550	7032

Ketchum's method makes the horizontal reaction to leeward about 10 per cent too great, Hutchinson's method makes it about 10 per cent too small. The effect of this may be summarized as follows:

Ketchum's method gives roof truss stresses too great on the leeward side, too little on the windward side. Hutchinson's solution gives exactly the reverse errors. Ketchum's method gives too great stress in the leeward kneebrace and bending in the leeward column, Hutchinson's method gives too little.

Comparing wind stresses in the two bents, the approximate stresses have about the same absolute errors in each for columns hinged. The rigidity of the roof truss does not play as great a part in wind load as in dead load.

Considered merely as solutions for wind stresses there is not much to choose between Ketchum's and Hutchinson's methods for the hinged bent, as may be seen from Tables I and II, but when dead and wind load stresses are combined to get stresses governing design, interesting results are obtained. The roof truss design is governed, with the exception of one or two members leading from the kneebrace, by stresses on the windward side of the truss. The approximate dead load stresses are too great. Ketchum's wind stresses on the windward side of the truss are too small. When added together the errors decrease. Hutchinson's windward stresses are too large. When the already too large approximate dead load stresses are added the errors in the final stresses are increased. The design of column and kneebrace is determined by the wind stresses in the leeward column and kneebrace. The approximate dead load solution, gives no stress in either, in consequence, Ketchum's wind stresses here, which were a little large, provide a margin to account for the true dead load stresses, while Hutchinson's wind stresses, already too small, become more still in error when compared with the true dead and wind stresses. Tables I and II show the errors in the ruling stresses for dead and wind load to run uniformly from 4 to 5 per cent. for Ketchum's method, while those for Hutchinson's method run up to 25 per cent. A table of the dead and wind load horizontal reactions follows:

DEAD AND WIND LOAD. COLUMNS HINGED.
HORIZONTAL REACTIONS AT BASE OF COLUNNS.

		Ketchum	*Hutchinson*	*True*
Bent One	Windward	4000	5100	
	Leeward	6200	5100	5695
Bent Two	Windward	5270	6550	
	Leeward	7830	6550	7451

Comparing the two bents, Bent Two shows slightly smaller errors than Bent One for dead and wind load stresses for both solutions, but the difference is not great.

The shortcomings of the equivalent uniform load method of design used in Bent One are seen from a comparison of the dead and wind stresses with the stresses from the shop drawings in Table I. Members 3-4, 4-5, 5-8, 7-8 have stresses much too small and the columns are too light. Figures 1 and 2 show that the diminished sections of these members permit greater distortion at the ends of the truss for Bent One than for Bent Two, which tends to increase errors in its stresses.

The tranverse bent with columns fixed is an arch with fixed ends so that in addition to the uncertainty as to the distribution of the horizontal shear at the bases of the columns there is an unknown moment at the base of each column. Corresponding to the moments at the bases of the columns there will be a point of contraflexure in each column so that if the points of contraflexure in the columns and the horizontal shear at each are fixed in some way, the vertical reactions and moments at column bases and the stresses in the bent can be calculated. The approximate dead load stresses are the same as for columns hinged. For the true dead load stresses the compression in the kneebraces is greater than before, 5000 lbs. for Bent One and 2324 lbs. for Bent Two, because the columns have been stiffened by fixing the bases. The true stresses are thus reduced and Tables III and IV show the approximate dead load stresses to have errors up to 127 per cent too large for Bent One and up to 84 per cent too large for Bent Two. The dead load deflections are shown in Figures 3 and 4. Bent

Two, with the stiffer roof truss, shows the smaller errors in stresses.

The dead load approximate solution takes no account of the bending and horizontal shear in the columns. The wind load solutions attempt to determine both and fix points of contraflexure and horizontal reactions as follows: Ketchum assumes the columns to deflect equally at the top and foot of kneebrace as will be the case for a perfectly rigid truss. From an investigation of the leeward column, he then shows ("Steel Mill Building," 3d ed., p. 87) that the point of contraflexure is independent of the horizontal shear and is given by the formula

$$y=\frac{d}{2}\left(\frac{d+2h}{2d+h}\right)$$

where h=height of column and d=height to foot of kneebrace. Substitution in this formula shows that y will be a minimum and equal d/2 when d=h and this value is selected for the heights of the points of contraflexure in both columns. Figures 3 and 4 will show that the points of contraflexure are nearly the same height for wind stresses. The horizontal reactions at the points of contraflexure are obtained by dividing the horizontal wind load above the points of contraflexure equally between them. The net reaction to windward is then obtained by subtracting the wind concentration from the upper part of the column. The vertical reactions are determinate, knowing the heights of points of contraflexure, and the stresses can be calculated. This is Ketchum's standard method, designated Ketchum's Method I in this paper. As a refinement on this method, though not recommended by Ketchum, an approximate solution for wind stresses was used in which y was determined from the formula already given. The reactions were then obtained as before. This solution is designated as Ketchum's Method II. Both these methods reduce the horizontal shear in the leeward column over the case for columns hinged at base. Hutchinson assumes the columns to act as if fixed at the base and supported at the top and investigates the leeward column for the point of contraflexure

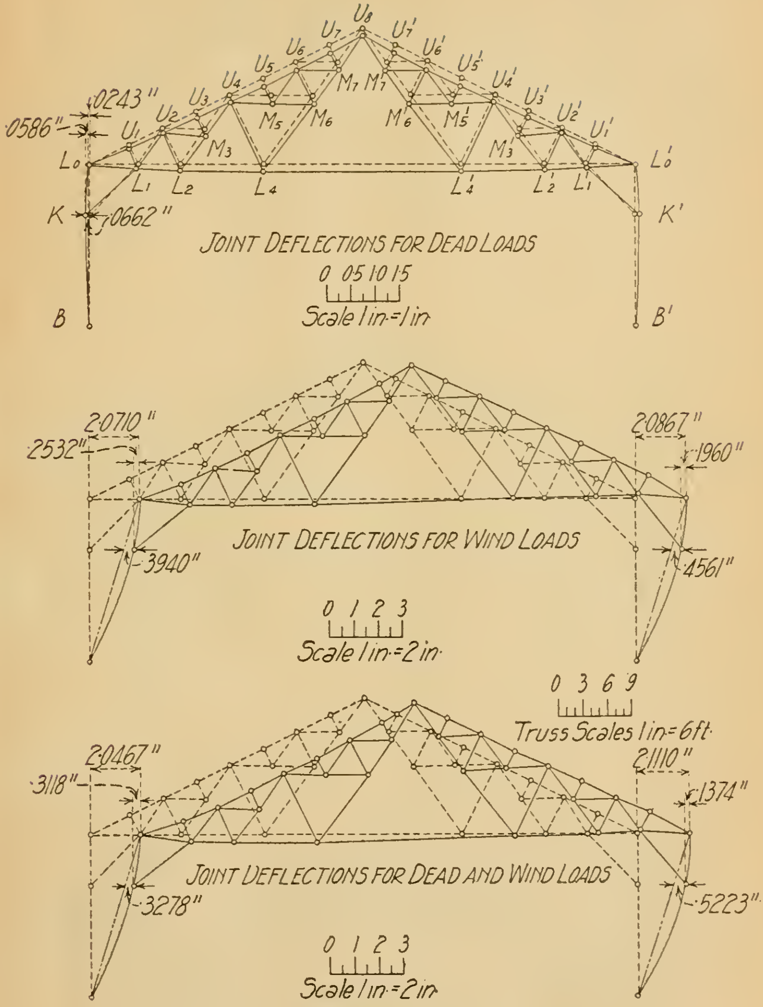

Fig. 1. Bent One. Columns Hinged.
Joint Deflections.

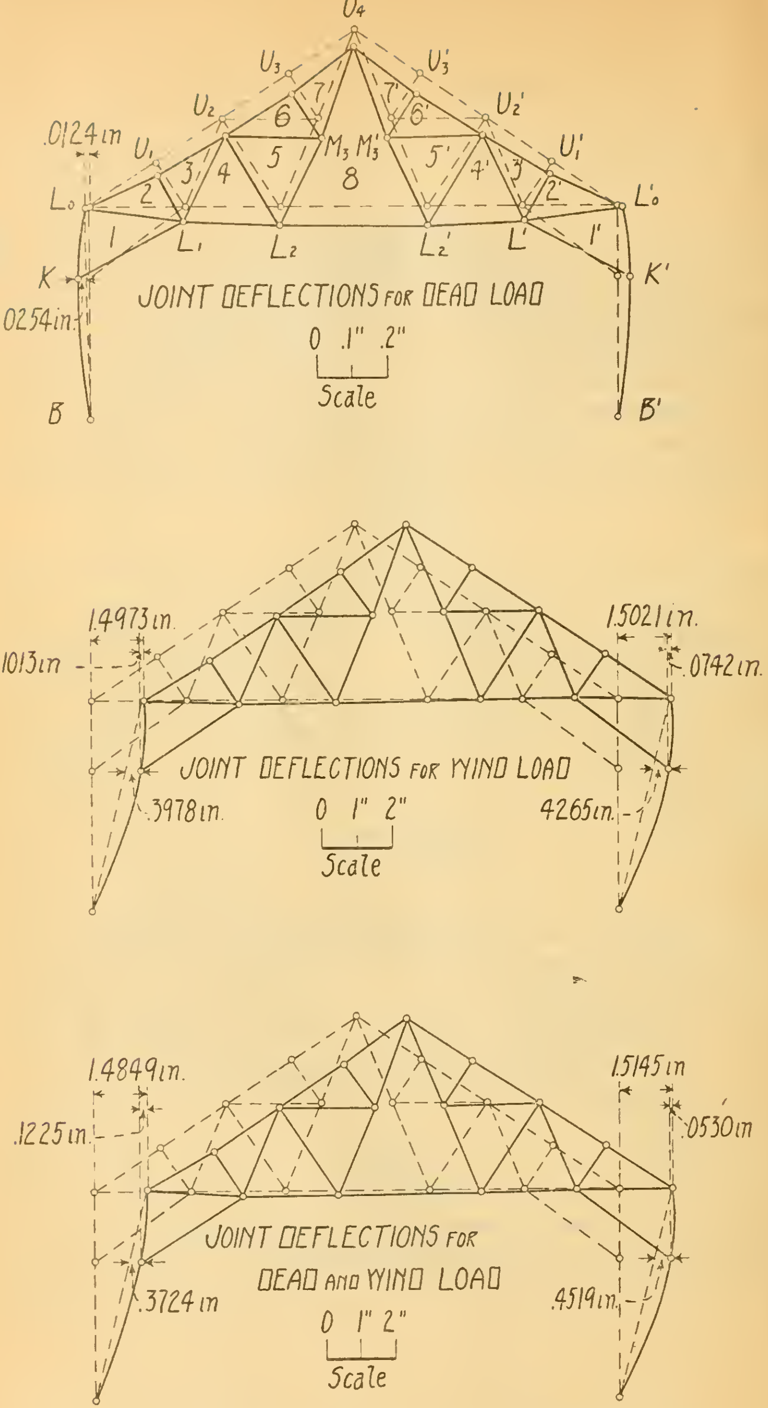

Fig. 2. Bent Two. Columns Hinged.
Joint Deflections.

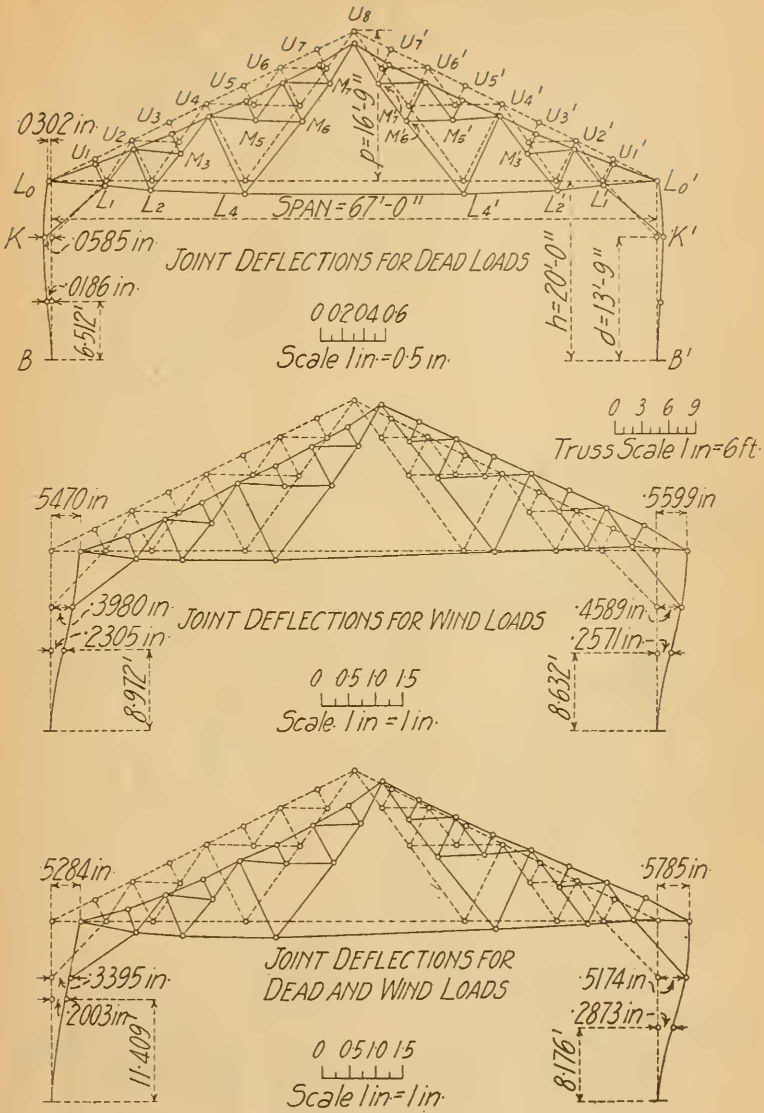

Fig. 3. Bent One. Columns Fixed.
Joint Deflections.

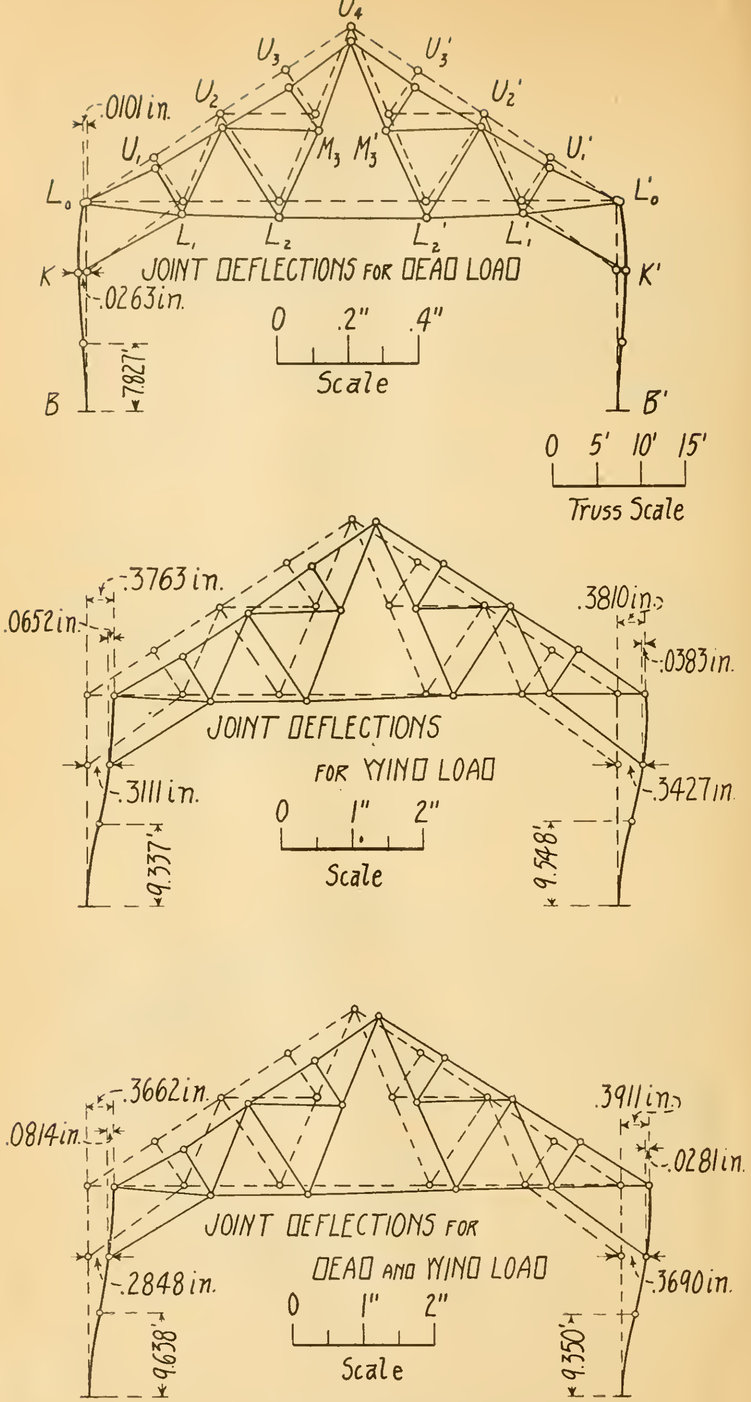

Fig. 4. Bent Two. Columns Fixed.
Joint Deflections.

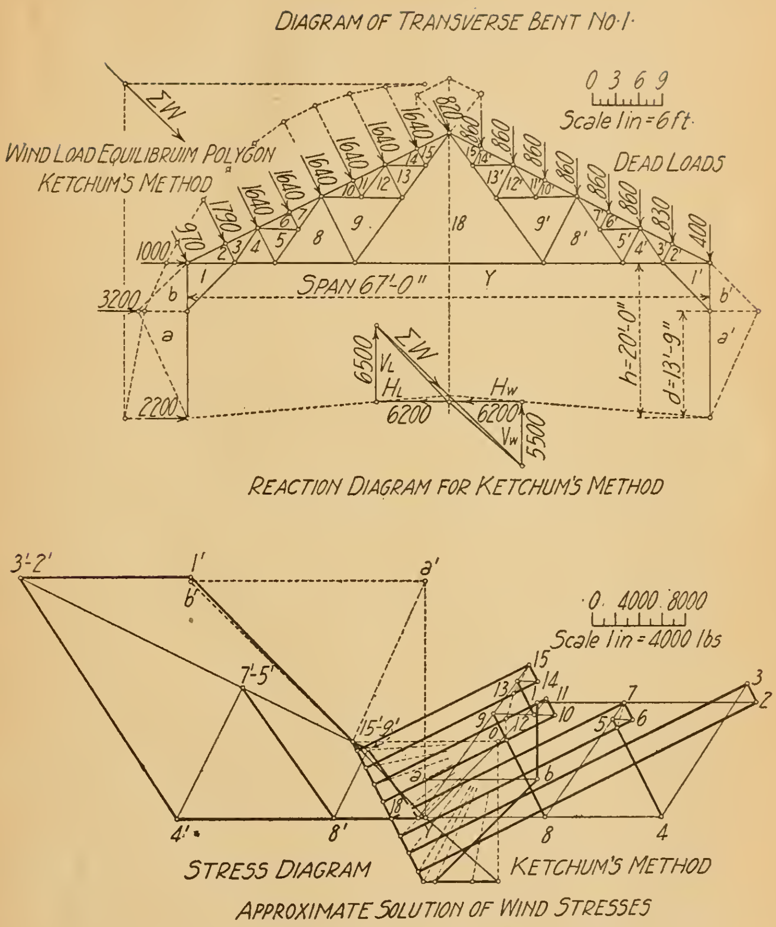

Fig. 5. Wind Stress Diagram. Cols. Hinged.
Ketchum's Method.

on this basis. Hutchinson's formula for the height of the point of contraflexure is

$$y=h-\frac{2(h-d)}{2-3k^2+k^3}$$

where $k=d/h$. y is independent of the horizontal shear. The height of point of contraflexure is calculated by this formula and assumed to be the same for each column. In determining the horizontal reactions Hutchinson does not reduce his horizontal wind force by the wind load below the points of contraflexure, but keeps the reactions as they were for the bent with hinged columns. The solution checks because the wind concentration at foot of windward kneebrace is kept as for hinged columns. Theoretically, this concentration should be reduced on account of the wind load carried by the column below the point of contraflexure and the reaction reduced also.

Errors in stresses for the fixed bent are due both to incorrect heights of points of contraflexure and incorrect division of the horizontal wind load between the horizontal reactions. Errors in both may compensate each other in part of the bent. The following is a table of horizontal reactions and points of contraflexure for wind load in pounds and feet:

Wind Load. Columns Fixed.

	Horizontal Reactions				Points of Contraflexure			
	Windward		*Leeward*		*Windward*		*Leeward*	
	Bent I	*Bent II*	*Bent I*	*Bent II*	*Bent I*	*Bent II*	*Bent I*	*Bent II*
Ketchum's Method I..	4000	5320	5100	6600	6·875	8·00	6·875	8·00
Ketchum's Method II.	4000	5320	4956	6420	7·780	9·143	7·780	9·143
Hutchinson's Method.	5100	6600	5100	6600	6·201	7·382	6·201	7·382
True Solution.......			5898	7148	8·972	9·337	8·632	9·548

The above table shows that all approximate solutions have the horizontal reaction to leeward too small, and the points of contraflexure too low, though Ketchum's formula used in Ketchum's Method II gives good results for the latter. The leeward horizontal reactions are all much in error. The deficient leeward reactions cause stresses on the leeward side of the truss to be too small and on the windward side too great. The low points of contraflexure cause all stresses to be too great with the possible exception of moments in the columns. An examination of Tables III and IV shows that Ketchum's Method I gives on the whole most satisfactory stresses in the roof truss, and Ketchum's Method II gives the best column moments. Figures 3 and 4 show that Ketchum's assumption that the foot of kneebrace and top of column deflect equally is close to the truth. Hutchinson's assumption with regard to the columns is much in error. His point of contraflexure is far too low, so much so that he gets his maximum moment at foot of kneebrace instead of base of column where it belongs. In general the approximate wind load solutions give stresses too great in the roof truss and moments too small in the leeward column. Comparing the two bents the errors in stresses are distinctly greater for Bent One than for Bent Two.

The combination of dead and wind load stresses for the bent with columns fixed increases the errors of all approximate solutions. A table of horizontal reactions and heights of points of contraflexure in pounds and feet is given below:

DEAD AND WIND LOAD. COLUMNS FIXED.

	Horizontal Reactions				Points of Contraflexure			
	Windward		*Leeward*		*Windward*		*Leeward*	
	Bent I	*Bent II*	*Bent I*	*Bent II*	*Bent I*	*Bent II*	*Bent I*	*Bent II*
Ketchum's Method I..	4000	5320	5100	6600	6·875	8·00	6·879	8·00
Ketchum's Method II.	4000	5320	4956	6420	7·780	9·143	7·780	9·143
Hutchinson's Method.	5100	6600	5100	6600	6·201	7·382	6·201	7·382
True Solution.......			7512	8072	11·409	9·638	8·176	9·350

The increase in the leeward reaction due to the dead load is marked.

The order of best results for the three approximate wind load solutions for a bent with fixed columns in combination with the approximate dead load stresses is shown to be as follows from Tables III and IV. For ruling stresses in the roof truss, Ketchum's Method I, Ketchum's Method II, Hutchinson's Method with stresses about 50, 50, and 60 per cent too great for

Bent One and 20, 20, and 30 per cent too great for Bent Two, respectively. For ruling stresses in the kneebrace and connecting members, Hutchinson's Method, Ketchum's Method I, Ketchum's Method II, with stresses about 25, 30, and 35 per cent. too small for Bent One, and 7, 10, and 20 per cent. too small for Bent Two, respectively. For maximum bending moment in the columns, Ketchum's Method II, Hutchinson's Method, Ketchum's Method I, with stresses 37, 37, and 43 per cent. too small for Bent One, and 22, 25, and 30 per cent. too small for Bent Two. Hutchinson's maximum moment is in the wrong place. The points of contraflexure are nearly on a level for Bent Two (see Figure 4) and are very close to the height given by Ketchum's formula cited on page 260 and used in Ketchum's Method II. Ketchum's Method I and Hutchinson's Method come next in order of approximation. The same order of results exists for Bent One, but the weakness of the members connecting the kneebrace causes an undue sagging of the roof truss and compression in the kneebrace for dead load so that there is actually a compression of 260 lbs. in the windward kneebrace for dead and wind load. This raises the point of contraflexure in the windward column. The dead and wind load deflections may be studied in Figure 3. The dead and wind load deflections tend to counterbalance one another on the leeward side of the truss so that the point of contraflexure in the leeward column of Bent One is closely at the height given by Ketchum's formula. (See page 260.) The errors in stresses just given show that the defects in design in Bent One are accompanied by increased errors in stresses and may be their principal cause. In final reference to the equivalent uniform load method of design it should be stated that this method always leads to connecting a kneebrace designed by rule-of-thumb with a secondary member of the roof truss in which the stress as figured by the usual vertical load methods is small. The member should not be expected to carry wind stress. The practice is not consistent. In spite of the different design of the two bents the order of accuracy of the different methods of computing wind stresses is the same, which leads to confidence in the deductions made for the tranverse bent in general. The reasons for the order of best results chosen for the different methods are best seen by studying stress errors in Tables III and IV.

There are two other combinations of loads used to determine ruling stresses for design; dead and maximum snow load, and dead, wind and minimum snow load. They were not worked out in detail in this paper because the stress errors for these loadings can be predicted from tthe results already worked out. For dead and maximum snow loads the errors in stresses will be exactly the same as those for dead load stresses for both columns hinged or fixed. Members designed by this system of loading will thus be on the safe side, but will be uneconomically large because of the large errors in dead load stresses. For dead, wind, and minimum snow load stresses, the errors will be usually slightly and uniformly greater than the errors in stresses for dead and wind loads for both columns hinged or fixed. With Ketchum's Method and hinged columns the errors may be less. The order of accuracy of the different solutions will not be changed. Calculations for this loading are easily made from Tables I to IV. The minimum snow load is usually taken at 10 lbs. per square foot of horizontal projection. The required dead, wind, and minimum snow load stresses may thus be obtained by adding the proper proportion of the dead load stress to the dead and wind load stress for each member. As an example the approximate dead, wind, and minimum snow load ruling stress in 2—x for Bent Two, columns fixed, using Ketchum's standard method for wind stress is —24140—7570= —31710 lbs. The true stress is —19745—5080= —24825 lbs. The error will be +27·7 per cent, instead of +22·3 per cent as for the dead and wind load stress. The corresponding stress in 2—x for Bent One, columns hinged, using Ketchum's Method I, will be—57670 lbs., the true stress — 50950 lbs. The error is +13·2 per cent. in stead of +4·7 per cent.

The results of the investigations up to this point show that for a tranverse bent with hinged columns Ketchum's solution for wind stresses is without question to be preferred and is very satisfactory. In combination with the dead load stresses the errors in stresses will be about 5 per cent. If minimum snow load stresses are added the errors will be about 15 per cent. For the transverse bent with fixed columns none of the solutions is very satisfactory, but Ketchum's standard method, Method I, seems to give on the whole the best results. The errors for dead and wind load stresses will be about +20 per cent. for the roof truss, — 10 per cent. in kneebrace and connecting members, — 30 per cent. for the columns for a well designed bent, but may run up to +50, —30, and —40 per cent for a poor design. For dead, wind, and minimum snow load stresses the errors will be about +30, —20, and —40 per cent. for a well designed bent.

An approximate solution for wind stresses in the transverse bent with fixed columns, which shows errors in ruling stresses running up to 30 or 40 per cent. on the unsafe side, can hardly be considered entirely satisfactory. The building in this case is not assumed to have other sources of lateral stability than the strength of its bents. The design in such a case should be on a different basis.* The following solution for the bent with fixed columns is, therefore, proposed as a revision of Ketchum's standard method. Fixing the columns of a transverse bent does not decrease the horizontal shear at the base of the leeward column for wind stress. The wind load horizontal shears at base of leeward column for columns fixed are for Bent One, 5898 lbs.; for Bent Two, 7148 lbs. The corresponding shears for columns hinged are 5698 lbs. and 7032 lbs. The shears show a slight increase which is augmented by the dead load stress. In the proposed solution the horizontal shear in the leeward column at its base will be taken at half the gross horizontal wind load above the column bases. This shear will also be the horizontal reaction at the leeward point of contraflexure. The horizontal reaction at the windward point of contraflexure will be half the gross horizontal shear less the wind load on the column up to the point of contraflexure. From this must be subtracted the wind load concentration from the upper part of the bent to get the net reaction. The points of contraflexure may be placed at any height which suits the designer, but should be at or below the height given by Ketchum's formula, cited page 260. For columns assumed absolutely fixed they will be at this height, if assumed partially fixed they will be below it. The vertical reactions are determinate knowing the heights of points of contraflexure. Bent Two has been worked out by this method and the results given in Table V. The columns were assumed absolutely fixed and the points of contraflexure located by Ketchum's formula. The height was 9·143 ft. The gross horizontal wind load was 15760 lbs. The leeward horizontal reaction was thus 7880 lbs., the windward, 7880—(320×9·143)=4960 lbs. The remainder of the solution follows Ketchum's method exactly. The horizontal shear at the points of contraflexure is the same for the proposed as for his method, the difference is in the division of the shear between the reactions. Ketchum divides it equally, that is, each reaction as he divides the shear would be half of 4960+7880=6420 lbs. This places too little shear in the leeward column. Ketchum's graphic solution for the reactions may be used as for his method.

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*See "Wind Stresses in Steel Mill Buildings," by R. Fleming, "Engineering News," Vol. 73, No. 5. Feb. 4, 1915.

Table V shows the errors in the ruling stresses calculated by the revised approximate method for fixed columns for dead and wind load to be less than 5 per cent and for dead, wind, and minimum snow load to be about 15 per cent. The errors of this solution as proposed for fixed columns are the same as those of Ketchum's solution for a bent with hinged columns. The result appears to confirm the consistency of the proposed solution for fixed columns as compared with Ketchum's solution for a bent with hinged columns. The recommendation is therefore made that for a transverse bent with hinged columns Ketchum's solution for wind stresses be used, and for a transverse bent with fixed columns, the revised approximate solution be used with the height of points of contraflexure fixed by Ketchum's formula.

TABLE V.

STRESSES USING REVISED APPROXIMATE METHOD FOR WIND STRESSES BENT TWO, COLUMNS FIXED

Member	Wind Load		Dead Wind Load		Dead. Wind, Min. Snow	
	Stress lbs	*Error %*	*Stress lbs.*	*Error %*	*Stress lbs.*	*Error %*
X-Y	—5152	—1·3	—9952		—14752	
1-X	—8660	—10·2	—13460	+3·0	—18260	+10·7
1-Y	+5920	—20·6	+5920		+5920	
1-2	+5100	—16·7	+11400	+0·9	+17700	+7·5
2-X	—12850	—12·4	—20420	+3·4	—27990	+12·7
3-X	—12850	—12·4	—19755	+3·5	—26660	+13·5
3-4	+7070	—12·5	+7970		+8770	
4-Y	+5130	—26·6	+10530	+5·6	+15660	+20·9
4-5	—9400	—5·4	—11400	+2·7	—13400	+9·2
6-X	—9640	—9·7	—15880	+1·4	—22120	+6·6
7-X	—9640	—9·7	—15215	+1·4	—20790	+7·0
5-8	+8440	—5·8	+10240	+2·3	+12040	+6·9
7-8	+11720	—4·3	+14420	+1·6	+17120	+6·0
8-Y	—3400	+72·6	+200		+3800	
7′-8	—5840	+13·1	—3140		—440	
5′-8	—5840	+13·1	—4040		—2240	
7′-X	—2770	—27·9	—8345		—13920	
6′-X	—2770	—27·9	—9010		—15250	
4′-5′	+6480	+13·1	+4480		+2480	
4′-Y	—9170	+28·5	—3770		+1630	
3′-4′	—11620	+12·5	—10720	—1·9	—9820	—14·8
3′-X	+6870	+44·7	—35		—6940	
2′-X	+6870	+44·7	—700		—3270	
1′-2′	+970	—46·1	+7270		+13570	
1′-Y	—18120	+12·9	—18120	—1·4	—18120	—12·5
1′-X	+3800	+43·9	—1000		—5800	
X-Y	—6962	+1·0	—11762	+0·6	—16562	+0·4

EXTREME FIBER STRESSES IN COLUMNS. LBS. PER SQ. IN.

Wind. Kn. Br..	3980		3980		3980	
Wind. Base...	7320		7320		7320	
Leew. Kn. Br.	8100		8100		8100	
Leew. Base...	10830		10830	—4·6	10830	—12·9

If the designer chooses to assume a partial fixing only of the columns at their bases, the points of contraflexure will be lowered to a selected height, the leeward horizontal reaction will remain the same, and the windward horizontal reaction at the point of contraflexure will be half the total horizontal wind force above the column bases less the wind load on the windward column up to the point of contraflexure. The errors of all solutions should remain about the same, 5 per cent. for dead and wind load stress and 15 per cent. for dead, wind, and minimum snow load stress for a well designed bent. The usual method of computing dead load and vertical load stresses is recommended, the stresses to be combined with the wind stresses computed by the above given methods.

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THE SENSITIVENESS OF SOME CYANIDE REACTIONS.

By John B. Ekeley and Icie C. Macy.

There has been some disagreement among authorities concerning the delicacy of certain tests for the presence of cyanides, notably the Prussian Blue test and the hanging drop test with silver nitrate. Since the question of their delicacy is certain to be a subject of controversy in forensic cases, it seemed to be important to make further experiments to determine, if possible, the delicacy of these tests to the closest point. Since the question of the delicacy of the Schönbein test has been a subject of cross-examination in a recent case in the courts, it was thought well to make further experiments with this test also.

Prussian Blue Test. Link and Möckel[1] state that this test is positive up to dilutions of 1:50,000, while Wormley[2] states that it is sensitive up to dilutions of 1:25,000, these figures referring to the distillate obtained from the suspected material after acidification with tartaric acid.

The delicacy of this test was worked out using first, pure potassium cyanide solutions of known strength, and then the distillate obtained from similar solutions after acidification with tartaric acid.

Tests Upon Potassium Cyanide Solutions Direct. A solution was made by dissolving one gram potassium cyanide in 100 c.c. of distilled water. The exact strength of this solution was determined by titration against standard silver nitrate.

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1. Link and Mockel: Zeit. für an. Chem. 1878. xvii, 455.
2. Microchemistry of Poisons. 2nd. Ed. 183.

Solutions were then made up in dilutions from 1:1,000 to 1:100,000. Two cubic centimeters of potassium cyanide solution were used in making the test in each case. Each sample was first treated with one drop of a 5 per cent. solution of potassium hydroxide to make it strongly alkaline, after which three drops of a 3 per cent. solution of ferrous ammonium sulphate and one drop of a 3 per cent. solution of ferric chloride were added. In the presence of a sufficient amount of potassium cyanide a dirty green precipitate was formed. Five drops of a 5 per cent. solution of hydrochloric acid were then added and the solution gently warmed. In the presence of considerable quantities of potassium cyanide, the solution immediately assumed a blue color, and upon standing several hours a flocculent, blue precipitate was deposited on the bottom of the test tube. When minute quantities of cyanide were present the solution first turned slightly green in color and, after standing some hours, a very small amount of the blue precipitate was deposited. Hence, only in cases where a precipitate was produced, either immediately or after standing, was the test considered positive.

The following table shows the experimental results:

Dilution as KCN	*Immediate Color*	*Color After Standing*	*Conclusion*
1:1,000	Dark blue	Heavy blue precipitate	Positive
1:5,000	" "	" " "	"
1:10,000	" "	" " "	"
1:20,000	" "	Blue precipitate	"
1:30,000	Lighter blue	" "	"
1:40,000	" "	" "	"
1:50,000	" "	" "	"
1:60,000	" "	Slight blue precipitate	"
1:70,000	Blue green	Very slight blue precipitate	"
1:80,000	Greenish	Greenish blue sediment	Uncertain
1:90,000	Colorless	" " color	Negative
1:100,000	"	Greenish color	"

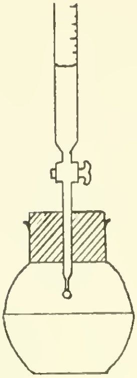
1:70,000 for KCN corresponds to a dilution of about 1:170,000 for HCN in the original solution.

Tests Upon the Distillate From Potassium Cyanide Solutions After Acidification With Tartaric Acid. Solutions of potassium cyanide were prepared with strengths ranging from 1:100,000 to 1:1,000,000. One hundred cubic centimeters of each solution was acidified with 10 c.c. of a 1 per cent. solution of tartaric acid and the whole distilled. Since hydrocyanic acid is very volatile, it is necessary to collect only the first two cubic centimeters of the distillate in order to obtain the total amount of the hydrocyanic acid in the solution. The distillate was then treated with potassium hydroxide, ferrous ammonium sulphate, ferric chlorid and hydrochloric acid as before and the colors and precipitates noted. The following results were obtained:

Dilution as KCN	*Immediate Color*	*Color After Standing*	*Conclusion*
1:100,000	Dark blue	Dark blue precipitate	Positive
1:200,000	“ “	“ “ “	“
1:300,000	Dark blue when cold	“ “ “	“
1:400,000	“ “ “ “	“ “ “	“
1:500,000	“ “ “ “	“ “ “	“
1:600,000	No change	Lighter blue “	“
1:700,000	“ “	Slight “ “	“
1:800,000	“ “	Greenish tinge	Doubtful
1:900,000	“ “	No change	Negative
1:1,000,000	“ “	“ “	“

One hundred cubic centimeters of a solution of KCN at a dilution of 1 :700,000 will give a definite test after acidification with 10 c. c. 1 per cent. tartaric acid and distilling off about two cubic centimeters. This corresponds to a dilution of about 1:1,700,000 of hydrocyanic acid.

Hanging Drop Method for Hydrocyanic Acid. A series of potassium cyanide solutions were prepared, varying from 1:100,000 to 1:1,000,000 in concentration. The apparatus used consisted of a burette, the delivery end of which was drawn out to capillary dimensions and fitted into a one-holed rubber stopper, which in turn fitted a 150 c. c. wide-mouthed flask.



A 1 per cent. silver nitrate solution was placed in the burette, and 100 c. c. of the cyanide solution in question, after acidification with sulphuric acid, 1:20, was placed in the flask. The rubber stopper was fitted tightly into the flask in order to avoid error that might be introduced by the effect of evaporation of the drop of silver nitrate, which was then allowed to hang from the tip of the burette. The silver nitrate drops were exposed to the vapors of the various solutions during 5, 10, and 15 minute intervals, and at the end of these time intervals, the drops were transferred to a microscopic slide and examined under the microscope for silver cyanide crystals. Silver cyanide crystals show very characteristic forms at various dilutions. With moderately strong solutions the silver cyanide crystals appear in the form of twinned wedges, while at high dilutions they form very long, slender needles. If the silver nitrate is exposed to the air too long there is danger of confusing silver nitrate crystals, which appear from the evaporation of the solution, with the silver cyanide crystals. The slide should therefore be examined quickly to avoid error of this kind. The following table shows the results obtained:

Trials	*Parts KCN to H_2O*	*After 5 Min.*	*10 Min.*	*15 Min.*	*Conclusion*
1	1:10,000	Crystals	Crystals	Crystals	Positive
1	1:100,000	"	"	"	
1	1:200,000	"	"	"	"
1	1:500,000	"	"	"	"
1	1:1,000,000	"	"	"	"
1	1:2,000,000	"	"	"	"
1	1:3,000,000	"	"	"	"
1	1:4,000,000	"	"	"	"
1	1:5,000,000	"	"	"	"
2	1:6,000,000	"	"	"	"
2	1:7,000,000	1. Uncertain	1. One group of 8	"	"
		2. Crystals	2. " " " 4	"	"
2	1:8,000,000	1. None	1. Two crystals	"	"
		2. Few scattered	2. Group of 3	"	"
4	1:8,500,000	1. None	1. None	1. None 2. Uncertain	
		2. "	2. "	1. Big crystal	
		3. "	3. "	3. None	Uncertain
		4. "	4. "	4. "	

The hanging drop method with silver nitrate therefor gives positive results with solutions of 1:8,000,000 concentration of KCN when 100 c. c. are exposed to the drop of nitrate for 15 minutes. This corresponds to a concentration of almost 1:19,000,000 HCN.

The Schönbein Test. Solutions of potassium cyanide were prepared in dilutions from 1:10,000,000 to 1:22,000,000. Guaiac paper was prepared by soaking strips of filter paper in a freshly prepared 3 per cent. solution in alcohol and letting them dry in a dark room. These papers were kept in the dark. A dilute copper sulphate solution, 0·5 g. in 1,000 c. c., was used. The tests on the various KCN solutions were carried out as follows:

Small, wide-mouthed flasks of about 150 c. c. capacity were fitted with corks, the corks being split so as to hold a piece of guaiac paper in the vapor above the KCN solutions in the flasks. Since the guaiac test paper is very sensitive to light, it was necessary to carry out the tests in the dark. Tests were also made in the light to determine the effect of light on the reaction. The potassium cyanide solutions, about 100 c. c., were poured into the flasks and the mouths closed by means of the corks which held the guaiac test paper, the ends of which had been moistened with the copper solution. Duplicate tests were made, one set of flasks being kept in the dark and the other in daylight for twenty minutes and compared at the end of the period. In the case of the more concentrated solutions the dry portion of the paper was turned blue in the light, but remained unchanged in the dark. Other pieces of guaiac paper, exposed alone at the time of the experiment, also were turned blue by the action of the light. It is, therefore, evident that this test must be made in the dark. Air also effects the paper, so it is best to carry out the test in closed vessels, for if a piece of guaiac paper is moistened with dilute copper sulphate solution and left exposed to the air for some time, it will give the identical color that it gives with cyanide vapors.

Solutions of chlorine, bromine, hydrogen peroxide, and hydrochloric acid were tested in the same way and were found to act in an analogous manner. With dilutions above 1:1,000,000 these substances gave no test either in the light or in the dark. Solutions of acetic acid and of formaldehyde were tried with negative results.

Schönbein states that hydrocyanic acid will give the test in dilutions up to 1:12,000,000 if performed in air, while Link and Möckle placed the limit at 1:3,000,000. The results of our experiments place the limit of the reaction at 1:18,000,000 in the light and 1:23,000,000 in the dark, for solutions of KCN, which corresponds to about 1:43,000,000 in the light and 1:55,000,000 in the dark.

The Schönbein test should, therefor, he carried out in closed vessels in the dark to get trustworthy results, and only in extreme dilutions does it indicate the presence of hydrocyanic acid and exclude the presence of other substances, which are known to respond at high concentrations.

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THE MANUFACTURE OF LUBRICATING PRODUCTS FROM WYOMING AND COLORADO CRUDE OILS.

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(Read at a meeting of the Society, February 12, 1921)

INTRODUCTION.

The principal products produced up to the present time from the steadily increasing output of crude oil of Wyoming and Colorado have been gasoline, kerosene, and fuel oil. It is also possible to make lubricating products from the Rocky Mountain crude oil. This paper will cover the manufacture of lubricating products from these oils and also, briefly, the equipment and construction of plant necessary for the manufacture of these additional products.

PETROLEUM.

First let us consider the nature of the petroleum which we have at hand and compare it in a general way with the petroleum in other fields of this country. Petroleum as it occurs in different parts of the world, varies widely in composition. Certain varieties are composed of open chain hydrocarbons, others are made up exclusively of cyclic hydrocarbons, and still others occur showing every possible gradation between these two extremes. Numerous classifications have been proposed, based on its chemical composition in general, or the presence of a substantial proportion of characteristic bodies, such as the paraffin series of hydrocarbons, the naphthene series, sulphur derivatives, nitrogenous bodies, benzols, terpenes, etc.

Open chain hydrocarbons predominate in the petroleums produced in the Appalachian field (Pennsylvania, New York, southeastern Ohio, West Virginia, Kentucky and Tennessee), the Lima-Indiana field (embracing western Ohio and Indiana), the Canadian and the Alaskan oil fields. These are non-asphaltic, and generally carry solid paraffines.

Both open-chain and cyclic hydrocarbons are present in the petroleums produced in the Illinois, the Mid-continental (extending over Kansas, Oklahoma, northern Texas and northern Louisiana in the neighborhood of Caddo and De Soto) and in the Mexican oil fields. These are representative of the mixed-base petroleums, and carry both asphalt and the solid paraffines, and it is to the latter class that our Wyoming and Colorado petroleums belong; that is, we have what is known as a mixed base petroleum to deal with, which I shall attempt to show adds to our difficulties in refining and producing many of the refined products.

CRACKING.

Let us also consider at the start a term which is very generally used in the oil industry today, and to which I shall have to refer several times, known as "cracking." Cracking has been described as destructive distillation with the explanation that even carefully conducted laboratory fractionation does not put compounds in the distillates which have the same composition as originally existed in the oil.

The hydrocarbon series in which we are interested are shown by the formulae C_nH_{2n+2}; C_nH_{2n}; C_nH_{2n-2}; C_nH_{2n-4}; and C_nH_{2n-6}. We have very little to do with the last series, the aromatics (C_nH_{2n-6}), although some exist in crude oil or are produced in refining. These are produced mainly by the destructive distillation of coal in domestic gas plants and as intermediates form the foundation materials which are used for the coal tar dye industry and to a material extent for the production of military powders.

Of the hydrocarbons of a chemical series the simpler the molecule the lower the boiling point and the less the specific gravity. Thus in the C_nH_{2n+2} or paraffin series, the lowest compound that can form is CH_4 because when "n" for the carbon is equal to 1, the "2n+2" for the hydrogen is equal to 4. The higher members of this series are formed step by step by the addition of CH_2 with a resulting increase of boiling point and specific gravity. Methane (CH_4) is a gas at ordinary temperatures or has a boiling point of —165°C.

As the complexity of the molecule increases, we approach the point at which these compounds tend to be liquids at ordinary temperatures. Butane (C_4H_{10}) is the last compound of this series which is a gas at ordinary temperature, having a boiling point of 1°C. and the next one is a volatile liquid pentane (C_5H_{12}) which boils at 36°C. and has a specific gravity of 0·63.

The paraffin series hydrocarbons that in the main make up the ordinary gasoline produced by the distillation of crude oils, range from pentane to undecane ($C_{11}H_{24}$) with a boiling point of 195°C. and a gravity of 0·76. Kerosene may consist of those paraffin series compounds ranging from $C_{12}H_{26}$ having a boiling point of 214°C. and a gravity of 0·77 up to $C_{18}H_{38}$ having a boiling point of 307°C. and a gravity of 0·83. After this the true paraffin series compounds are solids which may range from $C_{20}H_{42}$, specific gravity 0·837, to $C_{35}H_{72}$, specific gravity 0·846.

Now these solids with so complex an arrangement of atoms to make up the molecules, cannot be vaporized at ordinary pressures unless they are in part carried over by the mass action of the vapors of some other fluid. Beyond a temperature of approximately 300°C. such complex molecules are unstable, that is, they tend to disassociate into the simpler compounds of lower boiling points and gravities.

As a result of various natural processes, crude oils are composed in the main of compounds of the true paraffin series in the more volatile cuts, such as gasoline and kerosene, and of hydrocarbons containing less hydrogen in the heavier or lubricating ends, with some paraffine in solution when the material is what is called a "Paraffin base" oil. These heavier ends have molecules, however, as complex as those indicated before for solid paraffine and would, therefore, be disassociated or cracked by straight fire distillation.

As the hydrocarbon molecule increases in the number of atoms, the percentage of carbon by weight increases and percentage of hydrogen decreases. Therefore, the formation of simpler compounds can produce elementary carbon as one of the end products. Without the production of carbon, $C_{30}H_{60}$, for instance, can form C_6H_{14} and $C_{24}H_{46}$ under ordinary distillation. The first would be a paraffin series (C_nH_{2n+2}) hydrocarbon falling into a gasoline cut and the second would remain behind and later fall into a lubricating cut. Undesirable rearrangements are formed by cracking into unsaturates, that is, those attacked by sulphuric acid of ordinary strength. As a result of such formations, a part of the oil is lost by the step of treating in the general refinery procedure. An increase of pressure raises the boiling point and therefore the amount of cracking. Many processes to produce a greater amount of the more volatile constituents at the sacrifice of the heavier, have been devised to take advantage of this physical principle. Whether this is desirable or not depends entirely upon the market conditions for the various products and the cost of the operation.

The practical way of producing cracking is to subject the distillate or heavy oil to high temperature conditions under pressure and the means usually employed for eliminating cracking is to introduce steam to the stills, which helps to throw over the distillates without material addition of heat beyond their evaporation temperatures. Cracking is of course essential in producing gasoline from distillate, and the elimination of cracking is essential in producing lubricating oils, for if cracked, the resulting distillates have lower flash and fire tests and run lower in viscosity, and the higher these can be maintained for lubricating products the better.

PRODUCTION OF DISTILLATE.

I am eliminating from this discussion the manufacture of gasoline, kerosene, etc., or, in other words, the light refined products and the necessary construction, which, by the way, has shown wonderful development during the past few years in obtaining capacity, heat efficiency, better separation of distillates, etc. I shall, however, wish to refer to this operation as it is here we obtain the distillate necessary for the production of one class of lubricating oils, and to make certain comparisons in case the fractions going into this distillate are left in the fuel oil, as is the common practice in skimming plants, and also where this distillate is used for cracking purposes in pressure stills for increasing the production of gasoline where pressure stills are available.

In any of these cases the first distillation of crude is handled in much the same manner, the differences being in the percentage of bottom or residuum left in the stills, the quantity of steam admitted to prevent cracking and the separations made in the distillates.

The stills used for this purpose may be of any size, but the improved practice today is to use stills approximately 14 feet 6 inches in diameter by 40 feet 6 inches long, holding a charge of 1,200 42-gallon barrels, with reasonable room for outage. Up to twelve of these large stills are connected together and run continuously. The crude oil is charged to the first still of the battery, usually slightly preheated by a heat exchanger, the temperature carried on the first still being approximately 250° F. The crude passes in turn from one still to the next, going from the front of the first to the rear of the second and so on, the temperature gradually increasing on each successive still, up to about 700°F. on the twelfth or last still of the battery. The flow is regulated by the height carried in each still and so arranged as to flow by gravity.

The stills are usually equipped with two towers, each of different design, and connected to the vapor line from the still in series. The idea is to provide expansion and slight cooling to the hot vapors, which in turn causes any heavy fractions to drop out. These are taken from the bottom of the towers to the receiving house through pipe coils, or worms, as they are commonly called, submerged in a water condenser, or they may be turned back to the stills for further distillation. By means of these towers, opportunity for three cuts or separations is available on each still, and in a battery of twelve stills connected together, of course 3x12 or 36 separations are possible. The crude oil is continuously pumped to the stills, the distillates are continually taken off, and the residuum from the last still continually pumped to storage, so that the whole distillation is handled as a continuous operation.

In some plants in the Eastern United States running on Mid-Continent crude, they carry the residuum in the last still as low as 6 per cent. of the crude charged, without coking the still. We have to be very careful to avoid having coke collect on the bottom of the last stills of the battery, in order to maintain continuous operation, for if the coke is deposited, it is necessary to cut out the still for cleaning, or run the chance of ruining the bottom. Of course, the smaller the yield of residuum, the greater quantity is available for distillate, and as the fuel oil residuum is a low-priced product, it is advantageous to run as low as practicable.

We have been unable to obtain results from our Wyoming crudes which compare favorably with the above, due to the fact that in most cases while the coke in the crude runs only about 2½ per cent., yet the wax content is very high and makes the residuum difficult to handle at the high temperatures. A yield from this operation shows approximately as follows:

	Per cent.
Gas naphtha	30·0
W. W. dist.	10·0
Light wax dist.	13·3
Heavy wax dist.	29·5
Heavy fuel oil	15·0
	97·8
Loss	2·2
	100·0

Somewhat the same results will be obtained by running the crude in single stills running either to a very heavy fuel oil bottom or to coke. If running to heavy fuel, the yield would be quite similar to the one previously furnished, and if running to coke, approximately as follows:

	Per cent.
Gas naphtha	30·0
W. W. dist.	10·0
Light wax dist.	13·3
Heavy wax dist.	42·2
Coke	2·2
	97·7
Loss	2·3
	100·0

The wax distillates from the above operations, so-called because they contain wax or paraffine, when properly prepared for the lubricating plant are called paraffine distillates, and become the base for paraffin, spindle, and neutral oils and paraffine wax. As a comparison, practically all of the distillate obtained between water white distillate and the fuel oil residuum, is suitable for cracking in pressure stills.

The paraffine distillate to be suitable for lubricating purposes, should be a dark amber color and have the paraffine carried in suspension in crystalline form, a pour test of not over 70°F., complete tests approximately as follows, although the more viscous and the lower the cold test the better:

Gravity	31·1° Beaumè
Flash	210° F.
Fire	330° F.
Cold test	70-80° F.
Viscosity	70-75 at 100° F.

The heavy wax distillate is therefore the most desirable for our purposes, although many times the wax is in the amorphous state instead of being crystalline, requiring rerunning for additional cracking, while usually we are able to draw a certain quantity of the light wax distillate suitable for our purposes which it is unnecessary to re-run. This rerunning is carried on in crude stills and the cracking carried only far enough to throw the paraffine into the crystalline form. If this operation is carried too far, we very materially affect the flash and fire tests of the oils produced from the distillate.

Chilling and Pressing.

The next process is the removal of the wax from the distillate, and it is done by first chilling the distillate by elaborate refrigerating equipment and chilling machines and then passing through large filter presses. In this operation the brine in the refrigerating equipment is usually chilled to 15 to 20°F.

The chilling machines are usually long double pipe coils 8″ and 10″ in diameter, 6 or 8 runs high, the inner pipe equipped with spiral conveyor. The brine is circulated through the jacket and the distillate containing the paraffine is forced through the inner pipe by means of the conveyors which continually keep the distillate moving as it solidifies, thus tending to granulate it and make it easier to filter.

The cooled and solidified distillate having the consistency of heavy mush, is transferred to high pressure filter presses provided with canvas covered plates, and while still cool, filtered at a pressure of from 300 to 500 pounds, causing the pressed oil to filter through the canvas, dropping into a trough and running by gravity to tanks, leaving the cake of slack wax in the rings of the press. After the press is full, or the pressure begins to run beyond safe limits, the pressure is taken off and the press loosened up and the rings cleaned of the deposit of wax, which is usually of a consistency which permits spading off with wooden spades. The slack wax drops into a spiral conveyor beneath the press and is conveyed to melting tanks equipped with steam coils for the purpose.

We shall want to come back to the slack wax and follow it through its additional processes, but first we will proceed with the pressed oil. Before doing so, however, I wish to give you a further idea of the equipment just described. The refrigeration required for chilling the distillate, will usually average one ton for each twenty 42-gallon barrels of distillate handled per twenty-four hours. The presses usually used have 450 plates and rings of 48-inch diameter, and will handle about 300 barrels of distillate per day with allowance made for cleaning.

The temperature at which the distillate is filter pressed is the controlling factor in determining the cold or pour test of the oil, the filter presses taking out the wax which will congeal down to this temperature, leaving an oil which when finally refined will show a cold test only slightly higher than the temperature at which filter pressing was accomplished.

REDUCING PRESSED OIL.

The pressed oil now has a dark red color, very clear but viscous appearance, testing as follows:

Gravity	29·1° Beaumè
Flash	200° F.
Fire	320° F.
Viscosity	75-80 at 100° F.
Cold test	20° F.

You will note that the greatest change after pressing is in the cold test, which has been reduced from 70-80 to 20, although there are slight differences in the gravity, flash, fire and viscosity, due to the removal of the paraffine.

It is this material which we are now ready to reduce to various viscosities, with corresponding variations in gravity, flash and fire tests, for the production of a general line of light lubricating oils. This reduction is usually accomplished by a battery of six to eight 800 to 1,000-barrel stills equipped with one tower and operated continuously along the same general plan as described for running crude oil.

The residuum in the last still is of course the heaviest product for which we are running, the other products varying in viscosity, gravity, flash and fire tests as we proceed from the first to the last still. This operation is carried on with limited quantities of steam in the various stills so as to prevent cracking and the reducing of flash and fire tests.

TREATING PARAFFINE OILS.

We now come to the final purifying and coloring of these various products which, in a general way, is accomplished by one of two processes, the first called acid treating and the second by filtering. We have shown how the solid paraffines are removed from the oil, and while much of the asphalt, due to our mixed base petroleum, is left in the fuel oil as a result of the first distillation, yet there is still some of this material present after the filter pressing and second distillation. This must be removed in order to produce satisfactory oils.

As previously indicated, one method is by acid treating which involves treating the oil with sulphuric acid in large agitator tanks equipped with cone-shaped bottoms and facilities for blowing the mass with air to facilitate close contact with the acid. We find that 98 per cent. acid is superior to the 93·5 acid for treating lubricating oils.

The quantity of acid used in making oils running from 70 to 280 viscosity at 100, ranges from 10 to 20 pounds per 42-gallon barrel, depending upon the color desired and the viscosity of the product. In general, the more acid used the lighter the color, which may be due to a more complete separation of the asphalt, unsaturated hydrocarbons and other hydrocarbons united with other chemical elements from the oil.

The asphaltic tar and spent acid settle to the bottom of the agitator and both are drawn off, the acid in turn separated from the tar and restored for further use. The oil is then transferred to neutralizing tanks which resemble the agitators in construction, and the free acid neutralized with caustic soda, soda ash or similar product, the quantity required usually ranging from 1 to 2 pounds soda ash per 42-gallon barrel. The oil is also washed with hot water, which settles to the cone of the neutralizing tank, together with the spent caustic, and is drawn off to the sewer.

With some of the lighter products the oils may be finished in the neutralizing tanks, but with the heavier ones it is difficult to drive out all the moisture, and the oil is transferred to bleacher tanks, usually covered by a building. These tanks are relatively shallow, usually about 30 feet by 30 feet, 5 feet to 6 feet high, equipped with coils for washing with water and blowing with air. This equipment gives an opportunity for more complete washing than can be carried on in the neutralizing tanks, and also an opportunity of blowing the moisture completely out of the oil.

After this process the oils are considered finished and ready for market and are represented by the samples I have here. You will note these samples represent products having considerable range of specifications and are recommended for various uses where comparatively light oils are required. In this process extreme care must be used to completely neutralize all acid used, and in turn to wash out all caustic, and last to dry out all water used.

Turbine, Automobile, and Spindle Oils.

Oils for turbine, automobile, and spindles usually have to stand very rigid demulsibility tests, which are impossible if the finished oils are not neutral, and in cases of this kind it is usually policy to use the second method of purifying which does not permit the use of acid, but instead removes the asphalt and other hydrocarbon impurities and gives the oil its color by filtering through Fuller's earth, bone black or similar substances.

Filtering.

This means of filtering is carried to very extreme lengths today in the manufacture of high grade lubricants and is highly specialized work, depending upon the class of oils produced. The greater part of the work is done by means of Fuller's earth as a filter medium of about 30-60 mesh.

The filtering is done in large vertical tanks holding from 25 to 50 tons of earth, the small size filter being usually eight feet in diameter and 25 feet high, the proportion of diameter to height usually about the same; or in other words, it is essential to have the height as great as practical in comparison with the diameter as the filtering is done in a vertical position, and in this way it gives the oil an opportunity to come in contact with the greater quantity of filtering medium. Special bottoms are provided and lined with canvas to prevent the earth coming through with the oil. Filtration is accomplished under slight pressure, 10-15 pounds, the oil passing through the bed of earth and continued until the filtrate reaches the limit of the colors prescribed. The oil is then finished and ready for market.

Many times the two methods of finishing are combined, and in that case the oils are first treated with acid nearly to color, neutralized, washed, and then filtered sufficiently to remove any acids and to bring the color up to the prescribed specification.

The amount of earth required for filtering varies considerably with the grade of oil and the color required. For example, a certain oil of 200 viscosity at 100, No. 3 National Petroleum Association color, requires 10 pounds of new earth per gallon, while in filtering cylinder stocks to "D" and "E" colors, stocks ranging from 155 to 250 viscosity at 212, require from 15 to 20 pounds new earth per gallon.

The bed of clay is then washed with hot naphtha while still in the filters. This dissolves much of the asphalt and other deposited hydrocarbons left on the earth. It is then removed from the bottom of the filter and subjected to heat treatment, similar to that used in burning cement, the purpose being to burn off the hydrocarbons which were not affected by the washing with naphtha, and after cooling, may be recharged to the filters. The usual life of the material ranges from 12 to 15 applications with gradually poorer efficiency. These filters are usually arranged so that from 16 to 20 comprise a plant, and in the plant is storage for the Fuller's earth, complete burning equipment and elaborate conveyor equipment for handling the earth to and from the filters, storage bins, burning equipment, etc. You may readily imagine that a plant of this kind is very expensive to build and operate and that oils produced in this way must bring a comparatively high price. The straight filtered oil is a much superior product for certain requirements, particularly those where low demulsibility tests are required.

ZERO COLD TEST OILS.

The specifications for high grade automobile oils usually require a cold test of 0° F., viscosity of from 225-260 at 100, with flash test around 400° F. In order to furnish an oil of this kind, it is necessary to chill and filter press twice instead of once, the brine for the second chilling being carried down to —5 or —10° F., which further complicates the operation. You can also appreciate that the losses in treating, filtering, distilling, etc., make the actual yield of products of this kind very small; in fact, Polarine, as made by one of the large eastern refiners, is handled substantially as follows: The material to start with is a combination of heavy paraffine distillate and a light overhead distillate produced in reducing pressed oil. This is re-pressed, treated, reduced to viscosity and filtered to color, and from the stock available, using Mid-Continent crude, taking into consideration the losses in the several operations, cuts the yield of Polarine to approximately 1 per cent. of the original crude (and there are different grades of Polarine), but I simply wish to indicate the care and precision which is required and used in the production of one of the high grade automobile oils with which you are all familiar; and our yield of products of this kind is still less, due to the higher paraffine and asphalt content of the crude.

FULLER'S EARTH.

Before going on, let me say a word about Fuller's earth. From 80 to 90 per cent. of the material used in the country is produced on the west coast of Florida and southern Georgia, and costs about $40.00 a ton, or 2 cents a pound laid down here. We have been searching this western country for similiar material or material which will do the work of Fuller's earth, but so far without much success.

Refined Paraffine Wax.

Now to return to the slack wax separated from the paraffine distillate at the filter presses, which by the way, usually runs with us 25 per cent. of the distillate. In view of the trace of asphaltic material and other impurities remaining in the slack wax, it is necessary to treat with acid, neutralize with caustic and wash in much the same manner as has been described for purifying oils by acid treating, although the quantity of acid required is comparatively small, usually about 5 pounds of 98 per cent. acid per 42-gallon barrel.

The slack wax still contains between 30 and 50 per cent of oily matters which are separated by a process known as "sweating." A "sweater" carries 8 to 10 superimposed shallow pans (40 feet by 10 feet by 10 inches) each provided with a wire gauze diaphragm stretched across longitudinally 8 inches below the top, also:

(1) An inlet for introducing the melted slack wax.

(2) An inlet pipe for water.

(3) An outlet pipe connected with the bottom of each pan at its center.

(4) A water circulating coil directly above the diaphragm through which cold water is first circulated to chill the wax, followed by warm water to induce the sweating.

(5) A steam coil directly below the diaphragm to melt down the wax after the sweating process is completed.

The operations are performed in the following rotation:

(1) The pans are first filled with cold water to ⅛-inch above the level of the screens.

(2) The melted slack wax is pumped into the pans to a depth of 4 inches and allowed to float on the water.

(3) Cold water is then caused to flow through the water-circulating system, which causes the slack wax to set into a solid mass.

(4) The water is then drawn off, whereupon the cake of solid wax settles upon the wire diaphragm.

(5) Warm water is then caused to flow through the water circulating coils at a temperature just below the melting point of the wax, which causes the oil matters to liquify and sweat out from the crystals of paraffine, with the result that the purified paraffine now known as crude wax remains on the wire gauze. The oily matter carrying a small proportion of wax in solution, known as foots oil, is drawn from the pans. The purified paraffine wax is melted by turning steam into the melting-down coils and drawn from the pans into a separate container. It takes about twenty-four hours to properly sweat a batch of slack wax.

The wax in this form usually contains a small percentage of oil and moisture. It is yellow to ivory in color and almost odorless and tasteless, and is called crude scale wax, which is the ordinary wax of commerce. We are furnishing it in melting points ranging from 118-134° F.

Refined paraffine wax is made by further sweating the crude scale wax and then filtering through Fuller's earth in the same manner as the oils are handled, requiring only about one ton of earth for from five to six tons of wax. The refined wax is white in color, entirely free of oil and moisture, odorless and tasteless, and is the product commonly met with in the retail market.

We find no difficulty in furnishing it in a wide range of melting points, practically the same as crude scale; that is, 118-134°F., in fact, our yield of high melting point wax is considerably higher than from any of the other crudes produced farther east of us in this country. Paraffine wax has almost entirely superseded animal and vegetable waxes, not only for candles, but for laundry use, waterproof paper, cartons, sealing preserve jars, and a multitude of minor uses.

It may be of interest to know that since starting our plant at Casper, Wyoming, we have shipped approximately one million pounds per month to the Orient, in addition to supplying gradually increasing domestic demand.

Cylinder Oils.

I now wish to outline in a similar manner the methods employed in producing heavy lubricants or cylinder stocks, and products which depend upon the cylinder stocks for their base. This latter division covers a large percentage of the oils on the market today. The cylinder stocks are made from the residuum of the crude petroleum instead of from the distillate, and is therefore an entirely separate and distinct development from the one previously described.

In this process the crude oil is topped, or the gas, naphtha and refined oil distillate are distilled off in batch or continuous stills, which means the removal of about 30 per cent. The residuum is then sent to the reduced crude treating plant where the material is treated for the removal of asphalt and other impure hydrocarbons, neutralized in very much the same manner as previously described for treating paraffine oils, the difference being that in this case all of the asphalt is still in the material treated. The amount thrown out is large, and therefore the treating loss comparatively high, running about 18 per cent. of the material treated or 12½ per cent. of the original crude.

The spent acid is separated from the asphaltic material thrown down in the agitator and restored, the remaining asphaltic pitch being the base from which, after further refining, excellent paving asphalt and similar products may be manufactured, all of which compare very favorably with similar products produced from native asphalts.

Reducing Cylinder Stock.

The treated reduced crude is now reduced in either batch or continuous stills with large quantities of steam admitted to the stills to prevent cracking. The distillates are driven off, as previously described, and the residuum is what is known as steam refined cylinder stock, or the base for steam cylinder oil. We have no difficulty in obtaining from certain crude petroleum found in the central part of Wyoming, cylinder stock of exceptionally high flash and fire test and extremely high viscosities. We obtain a stock of 680-700 fire and 600 flash with viscosity of 275-300 at 212, with a yield of 8-10 per cent. on the original crude, and where stock of lower tests is furnished, correspondingly higher yields. This stock would be the equal or superior to anything produced in the country for high superheated steam purposes, if it was not for one thing, and that is the high wax content in the crude which, by our ordinary methods of refining, we are unable to eliminate from the stock. This gives the stock an extremely high cold test.

We have tried to convince ourselves that we could furnish stock of this kind 70-80 cold test, although in many cases it runs over 100° F. and of course makes an unmerchantable product. Similar stock made from Pennsylvania crude, which by the way, is a straight paraffine base crude, and therefore requires no treating, usually runs from 40-50° F. This feature has been somewhat of a disappointment to us, but we are still working with it.

Filtered Cylinder Stocks

The better cylinder stocks are filtered the same as the light oils. On account of the high percentage of wax, we have found it necessary to dilute the stock with naphtha, using about 40 per cent. stock and 60 per cent. naphtha, filtering in solution, as we call it. Filtering usually increases the cold test, and you might think we would still have an unmerchantable product. However, it also changes the structure of the wax enough so that it will settle out at ordinary temperature, and by following this procedure we have been able to settle out enough so that the remaining oil, after steam stilling off the naphtha, gives us a cold test of 70-80, which compares favorably with other similar products, and we are able to produce oils of this character which are equal or superior to any produced in the country, on account of our naturally high flash, fire and viscosity tests.

The wax in the cylinder stock is amorphous in character and not at all like the crystalline wax in the paraffine distillate previously discussed, due to the fact that the paraffine distillate is cracked, while extreme care is used to avoid this condition in the case of the cylinder stock.

PETROLATUM

The wax settled out of the stock after distilling off the naphtha, is of entirely different character from the wax previously described, and is called petrolatum, which by the way, is the base for many drug store preparations with which you are familiar, such as vaseline, mentholatum, petrolatum, etc. I have samples of this product which is very unusual in character, having a melting point of 140-150, while most similar products will run about 120. It is also very stringy in appearance which, for many purposes, is very desirable. I also have small samples showing our efforts toward further refining this product, although as yet we are not very far along with the development.

BRIGHT STOCK

There is one more development which I would like to discuss, and this is the production of so-called bright stocks, or in other words, low cold test, highly filtered cylinder stocks. These stocks are the base for all high colored oils between the paraffine oils first described and the stocks.

The high flash and fire tests, together with the high viscosity and low cold test, makes it possible to use small quantities of the stock in connection with comparatively larger quantities of the lighter oils in producing a very complete range of products between the two limits described, and the specifications and appearance of these high grade oils are largely due to the quality of the bright stock used in the compounding.

The established process has been similar to the one just outlined for our filtered stock; that is, the steam refined stock is first placed in solution with naphtha, filtered to color, and the filtrate placed in settling tanks, heavily insulated, equipped with refrigerating coils at the top which permit cooling to from 0 to plus 10° F., with the result that larger quantities of petrolatum are settled, producing a much lower cold test stock, the usual specification for bright stock being 40-50° F.

The high percentage of amorphous wax or petrolatum in our stock makes our problem more difficult than the average. We are attempting to obtain the desired results by a new development which has been quite radical in the oil industry, and which if successful, will mean a very distinct step in the development. We are attempting to separate the petrolatum from the oil by means of centrifugal force, using large centrifuges specially designed for the purpose, this feature taking the place of settling tanks, the remainder of the process, however, being the same as I have previously described.

The advantages we expect to obtain over the established process are as follows:

Continuous operation.

More complete separation, which we estimate will be up to 15 per cent.

Lower cold test of the stock.

Our experimental work has indicated that we can produce without material difficulty a stock with cold test 20-25, which is quite remarkable, considering the nature of the stock to start with. Our plant is just starting, and I am not in position to furnish complete data as yet, but shall hope to do so at a later date. However, I have samples of the product and also samples of compounded oils made with the stock along the lines of the above discussion, all of which I trust may be of interest. The present indications are that while we have had to go to extreme measures to furnish bright stocks, that if we are successful along the lines of our development, we will be able to produce stocks which will be the equal or superior to any produced in the country.

CONCLUSION.

The above discussion completes in a general way the processes used in the development up to the present time. I have not attempted to go into the manufacture of greases, which is another possibility, but which up to the present time we have not done very much with. However, it is a separate business, and if of sufficient interest should be the subject for discussion by itself.

I have attempted to show by this paper the following:

(1) That it is impossible to tell from the appearance of an oil how it is made and its general characteristics.

(2) That oils should be bought on specification both as to physical tests with some knowledge of their manufacture.

(3) That our crude petroleum has very peculiar characteristics compared with those produced in other sections of the country.

(4) That it is possible to produce a full line of lubricating products from it, although requiring in some cases very special handling and very special processes.

(5) That this is particularly true in the production of cylinder stocks.

(6) That the nature of the crude makes the production of paraffine wax and asphalts suitable for road work, etc., particularly advantageous.

(7) That while we experience difficulty in the production of the several products, that with the possible exception of the unfiltered steam refined cylinder stocks, they are the equal or superior to any produced in the country.

(8) That the asphalt in the petroleum while it furnishes the unsaturates and increases our treating losses and other difficulties in refining, is the direct means of producing lubricating oils with high flash, fire and viscosity tests, and therefore an improved line of products.

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ASPECTS OF COLORADO'S OIL SHALE INDUSTRY.

By Arthur J. Hoskin.

(Read at meetings of the Society, May 30, and April 7, 1921)

As my title indicates, this paper is prepared especially for Coloradoans. I have listened to many addresses and have read many articles purporting to discuss American oil shales, but I seldom hear or read one that is not 80 to 90 per cent about foreign fields and practices. I assume that you care little what has and is being done with oil shales in Europe or Australia but are interested in what our own state will probably accomplish with resources of the same general character.

Oil Shale Defined.

In the first place what is oil shale? I hold that the word oil shale is a misnomer: that a more accurate name would be bituminous shale. However, I do not advocate any change, for the name is well established.

When we speak of oil sand or oil shale in the language of the petroleum field we mean a sandstone or a common shale that is saturated with natural or free oil. But this paper deals with an entirely different rock. True oil shale contains no free nor liquid oil. No oil can be recovered from it by chemical solvents nor by pressure. It, however, contains, or is impregnated with, minute organic substances which, when heated, will create oil. A piece of oil shale will become greasy if it be simply heated.

In Scotland the organic content of oil shale is known as kerogen. An American oil shale engineer has proposed the word petrogen to mean this same content. Such substance, especially in our Rocky Mountain shales, is the bituminized remains of vegetal elements chiefly, with some animal or fish elements. Occasionally very interesting pseudomorphs of marine plants and animals are encountered in our western oi shale deposits, these being similar to fossils but bituminous rather than silicious.

Geographical Distribution.

Oil shales are of more world-wide distribution than was until recently, realized. They have been noted in almost every state and country wherein sedimentary rocks abound. Geologically an oil shale is simply an enriched shale. If conditions were suitable, certain beds of mud became charged with the remains of sea life. This is about all that differentiates an oi shale from a common shale. In fact, in an oil shale country we find the valuable and the valueless shale beds interstratified.

Colorado contains a large portion of the most extensive and richest oil shale region thus far discovered in the world This region covers also a large portion of northeastern Utah and southwestern Wyoming. Our government has recognized the potentialities of this rock as a future national resource by setting aside as naval reserves two vast tracts, one in Utah and one in Colorado.

Colorado's Shale Field.

The oil shales in this great region belong to a Tertiary series known as the Green River, these lying immediately above the Wasatch series. The Colorado portion of this region occupies parts of Moffat, Mesa, Garfield and Rio Blanco counties. The greatest development has been in Garfield county. These resources are easily accessible from the valley of the Grand River which has been carved down through the Green River series into the Wasatch series. These deposits begin on the east about three miles west of Rifle and extend westerly into Utah.

The towns of Grand Valley and DeBeque are the centers for most of Colorado's proposed oil shale activities in the near future. At Grand Valley we have the Parachute Creek district; at DeBeque we have the Roan Creek district. These towns are thirteen miles apart on the main line of the Denver & Rio Grande Railroad. They are of about the same size, only 300 population each. This area has long been a livestock and fruit country.

VARIETIES OF OIL SHALE.

It is customary in our Colorado field to recognize at least three varieties of oil shale, such as the papery, the massive and the curly.

The most abundant is the massive variety which is rock that fractures into chunks or masses often with sharp edges. It is rather hard and tough. Its color depends upon its richness in bitumen. While most massive shale is blackish, there is much that is brownish. The weathered surface of massive shale is light blue but this oxidation is never deeper than the thickness of paper. This shale does not easily decompose nor disintegrate. Fragments of massive shale may be picked up miles from their source, along water courses, and found to be perfectly sound when broken open. The richer the shale, the greater is its resistence to destruction by natural processes.

Papery shale occurs in large beds. It is well named, for this shale, in weathering, splits into thin leaves conforming to the primary strata. The name Book Cliffs was given to the precipitous mountains north of the Grand River because of this phenomenon in the rocks. When a bed of papery shale is explored back into the mountain well beyond atmospheric influences, it is found compact, similar to massive shale. The papery consistency appears to be simply a special phase of weathering. In grade and color, papery shale is much the same as massive shale.

In the upper measures of the series there are frequently thin beds of very rich shale that has a wavy or curly structure. This is called curly shale. It is usually black.

The one important fact that differentiates a papery shale from the other kinds in our field is noted only when the shales are subjected to heat treatment. With the exception of the straight papery shale, our oil shales will, when heated in retorts, agglomerate or cake just as does coking coal. It partially fuses, becomes pasty and sticky and forms a solid mass unless kept continually stirred mechanically. Papery shale has no such habit and is therefore simpler in its treatment.

QUALITY OF OIL SHALE.

The richness of an oil shale is stated in its yield of total oil in gallons per ton of rock. Since methods of assay or analysis are as yet not standardized for this kind of work, different chemists may report discordant results from the same sample.

A person experienced in oil shale practice quickly judges the approximate quality or grade of a shale by its outward physical properties. Kerogen or petrogen imparts to shale its blackish or brownish shade, as already explained, and the intensity of the colors is an indication of the richness. Again, bitumen being of less specific gravity than shale, it follows that the richer an oil shale, the less is its weight; so that an experienced person can closely judge the grade of the rock by "hefting." A gradation of luster due to enrichment is another visual indicator. So, on the whole, the rock speaks for itself as to approximate quality.

The grade of oil shales varies up to perhaps 100 gallons per ton. I am aware that selected samples will yield up to 140 gallons, but I place little stock in such high figures as they will never represent commercial possibilities.

Since one gallon of the crude or total oil distilled from oil shale weighs approximately 6⅔ pounds, and since 1 per cent. of a ton is 20 pounds, equivalent to the weight of three gallons of the oil, we see that a shale that will yield 100 gallons per ton gives up one-third of its weight in volatiles. One hundred gallons per ton is far above the average grade of our Colorado oil shales.

Most promoters of oil shale companies base their estimates of production upon an average gross yield of one barrel or 42 gallons per ton. This is quite within the range of probability, but I personally prefer to base my estimates at 35 gallons, thus allowing liberally for contingencies and inefficiencies in eduction. Bear in mind, I speak of average shale.

STRATIFICATION.

The valuable shales are found in flat beds at all elevations within the thousands of feet thickness of the Green River series. It is an interesting fact that these beds have remained practically in their original attitude: for all practical purposes they are horizontal or flat. They actually have a very slight, inappreciable, dip toward the east. The strata of the entire series lie conformably. In addition to the barren and the valuable shale beds, there are sandstone beds, these being occasionally calcareous. The thickness of an enriched bed may vary up to about one hundred feet. Beds of this thickness are, however, uncommon.

There are certain beds that are so persistent as to serve as geological keys throughout the region. Lying directly upon a thick bed of red sandstone that forms the cap of the Wasatch series one will find a substantial, thick bed of papery shale, often 100 to 200 or more feet in thickness. Strata of this great bed are of low grade, but the bulk of the bed is rich, especially in paraffin. Usually the entire bed can be counted as good mill-feed. This is the base of the shale series and is not always exposed because it may lie beneath the surface of a property, even at the point of deepest erosion.

About a thousand feet (roughly) above the bed just mentioned there is another thick, persistent bed that is prominent because the extensive erosion of the gulches has left this bed exposed in very steep cliffs that are visible for many miles. A good view of these cliffs may be had from the Denver & Rio Grande trains.

It must not be understood that the entire thickness of the beds outcropping in these great smooth cliffs is of commercial-grade oil shale. In places these cliffs are several hundreds of feet high. I have heard oil shale men who are considered reliable claim to have 500 feet of workable shale in this zone. My own findings have proved a maximum thickness of 260 feet of such shale.

THE TOP COUNTRY.

As one views the shale mountains from the valleys or gulches and sees relatively little ground above the cliffs just described, he may deceive himself by assuming that he can see the tops of the mountains. The cliffs in question are generally spoken of as the rimrock and this nomenclature adds to the deception. As a matter of fact there may be hundreds or even a thousand feet of ground above what is the rim of a mountain, this top land having much less declivity and its surface sloping upward from the rim rock into a rolling country of considerable expanse, generally, with stretches of prairie and timber. Vegetation is strong and it is this top country that is utilized as range for cattle. The surface may be very rough and hills of considerable height may arise from this high plateau.

The Green River series prevails and there are frequently very rich beds of oil shale in this top country, as it is called. Access to the tops is possible by but very few trails, these usually being those built and used by the valley ranchmen in driving their cattle on top in the spring and down again in the late summer and fall at times of roundup. A few shale companies have constructed such trails within the past two or three years. The Denver weekly, known as The Great Divide, has endeavored to induce farmers to colonize and settle in this top country near Grand Valley. In the language of the oil shale men of that region the few settlers who have fallen for the inducements are known as Pinnacle Boomers.

CONTINUITY OF MEASURES.

There are no geologic faults displacing the Green River beds. The same beds may be observed at equal heights along both walls of a gulch, and any bed may be followed around a mountain from one gulch to the next. This fact gives assurance of the persistence of the beds and, in a measure, simplifies the matter of estimating natural resources.

There are changes in the quality of any bed. I wish to be thoroughly understood in my remarks regarding the continuity of these shale beds. While stating that the stratified measures persist without interruption for great distances, I am not asserting that they do so without any change in quality. As a matter of fact, any bed may be highly bituminous at one place while, perhaps in an adjacent mountain or even in an adjacent property on the same mountain, it may be lean or worthless. It is therefore not a certainty by any means that a specified bed will be oil shale in one property because it is enriched in a neighboring property. It is because of this recognized characteristic of these measures that one strong company plans to systematically core-drill its extensive holdings. This work will be done by sinking vertical holes from on top.

I would not wish to be misunderstood, on the other hand, as saying that any bed is sure to be of different quality in neighboring properties. As a rule the variations in the grade of any single bed occur gradually, not abruptly.

EXAMINATION DIFFICULTIES.

The examination of an oil-shale tract means hard physical labor on the part of the engineer, if he does an honest job. He must inspect all the strata from bottom to top of the entire series. He must carefully sample every bed that appears of commercial grade and is of workable thickness. He must get on top as well as up the cliffs. He must assume bodily risks in reaching many beds. He should never attempt an examination without a reliable assistant.

The Topography.

There is usually a different style of topography upon the southern and the northern faces of an oil shale mountain. The steepest cliffs are always upon the southern sides. The northern sides are much less precipitous, there is a great accumulation of slide-rock or debris, and there may also be a heavy growth of timber. There is always much less exposure of the measures in place upon the northern faces. Southern faces are preferable for mining activities and plant operations, not only for the above reasons but for the further reason that there is better shelter in the winter time with much less snow which leaves earlier in the spring.

Not every oil shale tract in the Colorado field possesses all of the valuable beds; or, if all such beds be present, some may not be practically workable. Erosion has been enormous. It has removed much more top from some mountains than from others. Again, the grade or slope of stream courses, governed by erosion, gives properties in the lower stretches of gulches a distinct advantage over properties nearer the headwaters of the same gulches, in that their lowest valuable beds have been naturally exposed or brought to the surface where they may be attacked by mining methods without shaft sinking. Bear in mind that these beds are flat.

Since the railroads and main settlements will always be in the lowest valleys of the region, it follows that distances from the main rivers will be factors in estimating the values of oil shale tracts.

Water Supply.

This region has a normal amount of rainfall, but owing to the rugged character of the topography, the run-off is in relatively few main channels or gulches. The top country has its streams, much as has any other rolling region, and these streams sometimes assume the form of beautiful waterfalls where they break over the rimrock.

Since water is a necessity in any camp for domestic uses and is positively required in the operation of some eduction processes, we see that consideration of water-supply is another function of a tract's value. This being a stock raising region in which it is required to raise feed for cattle during the winter months, we find that the ranchmen who occupy the tillable lands in the gulches have appropriated all of the water in the streams for irrigation purposes. This might seem a serious factor, but actually it is not. I have found these ranchmen most hospitable to every proposed oil shale project. I know instances in which they have readily granted reasonable quantities of their legal water rights to oil shale operators. I presume they appreciate the benefits that will accrue to them as producers of foodstuffs when the oil shale industry gets into its stride.

I was early told to expect opposition from these ranchmen if I attempted to locate oil shale claims covering the grazing areas on top. No such trouble has been met. The only conflict of this nature I have encountered was the instance of a squatter, not a ranchman, who claimed 160 acres of top land from which he could never hope to eke even a miserable existence. But I eventually secured his confidence, lived with him a few days in his cabin and actually used his services in surveying oil shale claims across his land. When it becomes clear to these men that oil shale activities will never seriously encroach upon their grazing areas, and when they are assured that they are welcome to continue grazing their stock upon the oil shale claims, they quickly drop any opposition they may have previously entertained and usually become cordial toward any proposed improvements in their vicinity.

OIL SHALE LOCATIONS.

Heretofore oil shale claims have been located exactly the same way as petroleum claims. It has been customary to follow the wording of petroleum notices and certificates by inserting the word *shale* after each occurrence of the word *oil.*

Claims are, then, placer locations, normally of 160 acres each, with eight claimants each. These placer claims are laid out according to the federal legal subdivisions. There are four forties in a claim and these forties may lie in any contiguous fashion that will best cover the desired land. Insofar as possible under this custom, the claims have been intended to hold ground that contains only the oil shale measures; but it has been impossible at times to get all of the valuable ground without including small areas of gulch land. In some cases the effort to secure only net oil shale land has been carried too far. When we stop to think about this point we can see that each property should possess a reasonable acreage that will serve as a camp-site, a plant-site, and dumping ground.

Each property should preferably contain a good stretch of what is called *frontage*, i. e., naturally exposed surfaces of the beds so that they may be readily attacked commercially.

Locators have almost invariably filed upon groups of claims. Each claim is given a name, the same as with mining claims. Possession of such claims is regulated by the same general requirements that apply to mining locations, as to annual assessments and patent procedure.

The passage of the federal land-leasing bill in February, 1920, put a stop to the location of oil shale claims. Hereafter the only way to secure government oil shale land is by lease from the government at an annual rental of 50 cents per acre. In a way this will prove an advantage, because the annual expense of holding a claim under a lease will be but $80 instead of the standard $100 imposed for assessments upon locations. No ownership will ever be acquired under the leasing arrangement, but offsetting this there will never be any taxes to pay upon the land.

The effect of this leasing act upon our Colorado oil shale industry will not be noticeable in many years, probably, for the reason that practically all the desirable land within reasonable distances of railroads was located prior to the enactment of the law.

There may be claims within the located areas that will revert to the government by reason of fraudulent acts of their locators or because of the non-fulfillment of annual assessment requirements. Such tracts will thus again become public domain and obtainable only under the provisions of the leasing law.

OBSCURED TITLES.

There is no doubt that there have been flagrant violations of the location laws, in many ways. Titles to oil shale properties require cautious inspection. This point is vital in determining the value of any property. Complete abstracts should always be demanded by prospective purchasers, and even these abstracts may require the scrutiny of persons well posted on conditions in this region.

There has been much claim jumping, intentionally as well as innocently. Many pieces of very good land will probably remain unworked a considerable time because of conflicting claimants. There are numerous instances in which dummy names were used as locators and deeds were fraudulently made out from these imaginary persons to the persons who were really locating the land for themselves.

HOW CLAIMS ARE ACQUIRED.

A word as to how the best oil shale lands may now be acquired. I have just explained that all of the easily accessible and most attractive land is at present held as placer locations. With but very few exceptions there are no patented oil shale groups. The land, therefore, is held merely by the possessory rights of location; but if the locations have been made strictly according to law, such rights are valid and transferable. Anyone desiring now to acquire a group of claims must purchase from the locators or their assigns. Titles are conveyed in quitclaim or miner's deeds. The actual title inheres in the federal government until patents are secured, but possession and ownership are guaranteed to a claimant so long as his requirements regarding assessment work are observed.

PRICES OF LAND.

The price of oil shale land is always stated in dollars per acre. Prices have ranged from fifty cents upward. They are going higher steadily. The average price one year ago for first-class land within twenty miles of a railroad was around ten dollars. The same lands could not be had today for less than twice that amount. To secure land now for $10 one must be satisfied to go at least thirty miles from a railroad. Desirable lands now command anywhere from $20 to $45. A recent deal on 1,320 acres called for the payment of the latter figure. I predict a doubling of prices again within another year.

It is usually possible to arrange the purchase of oil shale groups on the installment plan. However, even this practice is lessening and at present a seller demands either whole cash or he fixes the installments at short intervals. He knows that the price of his land will rapidly advance and he cannot well afford to tie up his holdings any considerable time.

If we were to estimate the worth of such land by the natural reserves it includes and were to set a value of only one cent per ton of commercially valuable and workable oil shale, an acre should sell for not less than $2,000. Upon this basis we note that the prevailing prices are purely arbitrary and really low.

SUBDIVISION SURVEYS.

One of the most annoying things with which Colorado oil shale claimants have to contend is the uncertainty over the federal lines of land subdivision. This region was officially surveyed by government contract many years ago but, probably because the work was carelessly done, the contractors' surveys were not approved or accepted by the General Land Office. A subsequent official survey was made with like results. As a consequence there are two disagreeing sets of section corners, neither set being recognized by the land office. The discrepancy between these surveys is considerable but it is not uniform throughout the field.

Abstracts of title may show two different claims on the same quarter section whereas, in the field, these claims may be half a mile or more apart. On the other hand, conflicting areas on the ground, if described by the different systems of subdivisions, will show no conflict in the abstracts. At one place in the region claims were located according to one set of corners, but a sale of these claims was frustrated because, during inspection, the prospective purchasers consulted a map drafted according to the other set of section lines and this map totally left off a whole tier of sections including the land in question.

If such cases ever get into the courts I have no doubt that the old rulings that monuments upon the ground prevail will hold good.

Covering a large portion of the Parachute and Roan Creek districts is still another subdivision, this having been made a few years ago by the U. S. Geological Survey. Inquiry at the office of the Surveyor-General brought the information that, while this survey may be accurate and was made by federal employes, it was not ordered by the General Land Office and has not been approved by that office. (Just another instance of the lack of co-operation between federal bureaus.) Wherever the metal monuments of this survey can be found, I adhere to them as being the most reliable. This survey disagrees with both the surveys previously mentioned. It would have been good practice to have described every location by metes and bounds with accurate ties to prominent landmarks. It is not too late now to file amended certificates incorporating this suggestion.

NATURAL RESERVES.

Because I know from experience that the question is both pertinent and reasonable, I am constrained to speak briefly on a point which, as an engineer, I prefer to avoid. I refer to the amount of raw material in a claim, or the tonnage of commercially-workable shale per acre. When one estimates these quantities the results are so startling as to seem illegitimate.

The average 42-gallon or 1-barrel shale will weigh about 18 cubic feet per ton as it lies in place in the ground. One acre is 43,560 square feet. Therefore, for every foot in thickness of the workable shale, each acre represents 2,420 tons. No worth-while oil shale tract will have less than 100 feet of workable shale, equivalent to 242,000 tons per acre. One claim of 160 acres will then contain 38,720,000 tons, which may produce the same number of barrels of crude oil. I am most conservative in these calculations in comparison with the estimates often given.

I am often asked how much land should be owned to warrant the erection of a big eduction plant. I always prefer to avoid a discussion such as I have just given, so I say that a single claim, if well located to give a reasonably large proportion to oil shale, with sufficient area for the plant and camp, will support a 500-ton plant for at least two hundred years. It were better to install several plants of 1,000 tons each.

Plant Sites.

The matter of plant-sites has been touched upon. It is a very important item in the worth of a piece of oil shale land. In our favored oil shale field, the workable beds lie high above the beds of streams. Plants can easily be erected at elevations that will permit the handling of the shale entirely by gravity from mine to mill-dump. Dumping ground must be ample to contain the vast tonnages expected to be treated. The plant must be built where it will most economically receive the mine's output, will be easily accessible, will have sufficient water supply, and will be able to operate the year round.

Hindrances to the Industry.

Probably some of you wonder why this building industry has been so slow in getting established. I could dwell at length upon many reasons for this delay and none of them would reflect any discredit upon the industry itself. I will touch briefly upon just a few such reasons.

In the first place the public was incredulous when early efforts were made to secure attention and investment. I know this to be a fact because I tried to start activities about ten years ago. Not until reports were published from the Federal Bureau of Mines and the Geological Survey did the public manifest any serious interest. This caused several years of delay.

Second, after these natural resources were finally recognized, the few enthusiastic pioneers met disappointment because their small duplicates of Scotch retorts failed to give favorable results. Owing to the caking character of our massive shale already mentioned, a Scotch retort cannot treat our Colorado massive shale. It was these failures of the foreign type retorts that spurred our oil shale enthusiasts to the invention of new processes.

Third, inventors as a rule, especially in their first efforts, are men of meager financial resources. The majority of our American inventors of oil shale processes have been unable to consummate their processes because they can not raise necessary funds. The great war was on in full blast when most of these inventions were conceived and our government frowned upon expenditures in new industrial fields. It is needless to remark that the prevailing financial stringency is not conducive to present progress along lines of developing untried things.

Fourth, in its inception this meritorious infant industry was overrun by unscrupulous promoters and given a bad name.

Fifth, there has been a persistent, subtle knocking of the industry by leaders in the petroleum industry. I presume this statement will elicit denial but I will stand pat on it. It is an interesting and significant fact that practically every large, influential oil company has surreptitiously acquired large holdings in our oil shale field in order to transfer its activities to the new industry when it gets ready to compete with other operators in the manufacture of oil. The knocking insinuations have been spread broadcast, especially among investing people. Why, even right here in Denver, there are prominent men who will advise the withholding of investments in oil shale projects for at least ten years. A little cogitation will show how such advice is traceable to selfish commercial interests.

The Commercial Side.

Thus far I have discussed items that may be said to enter into a general knowledge of the oil shale industry's resources and their acquisition. I have been obliged to omit many pertinent items. I propose now to proceed to some of the practical or operative phases of this new industry in our own region.

Mining Oil Shale.

The excavation or mining of the oil shale beds will prove simple. On a very few properties it will be possible, by starting with one or more of the lower beds, to operate a considerable time with quarrying or open-pit methods. This holds true because, in many instances, the lower slopes of the mountains are not nearly so steep as are the higher portions. Also there are a few instances in which open mining could be conducted above the rimrock, or on top, to very good advantage. I have in mind one property in which the topmost 200 feet is good oil shale.

Eventually, however, in the case of working the lower beds, excavation will have to proceed by underground methods. As in coal mining when a property contains numerous flat seams, it is advisable to first mine the highest seam, so should it be with shale mining. This precaution will probably be disregarded in many cases, for companies will decide to begin their mining operations in such beds as are most accessible, thus taking chances on ruining higher beds by the subsidence of the ground.

Underground mining of these beds will undoubtedly follow established coal mining practice, i. e., it will be either long wall or room-and-pillar mining. Shale is not a hard rock usually but it is much harder than coal. Some persons assert that oil shale can be mined as cheaply as can coal; but to me this is a matter of doubt and can be demonstrated only by commercial practice.

The drilling of massive shale cannot be done advantageously, as can the drilling of coal, with hand augers. However, the power-driven auger has proved successful. It is possible that light drills somewhat of the types of our common drifters and stopers used in quartz mining will prove entirely adequate. One of our progressive oil shale companies has reported success in the use of a new type of drill gotten out by this company. It is compact and easily portable, being designed especially for this class of duty.

One or two of the leading manufacturers of rock drills have stated their readiness and desire to perfect machines for this special kind of duty, if their present models prove inadequate. As soon as these manufacturers are granted opportunity to conduct experiments under practical operating conditions they will soon solve any deficiencies, I am sure. On the whole, then, I anticipate no particular difficulty in the matter of drilling.

The blasting of this rock will likewise present little or no difficulty, even from the start. Manufacturers of explosives have adapted their products to the rending of almost every sort of material and their researches have led them to knowledge that can be promptly applied to the oil shale problem. The market is already supplied with so many grades of explosives that it is improbable that any new grade will have to be made for this work. It will simply be a matter of making the best selection of explosives and learning to adapt them. I imagine we may find it necessary to use what are called low or slow explosives and that low percentage dynamites will be used. One company is using 40 per cent. dynamite.

Our oil shale is filled with stratification cleavages and is more or less elastic as well as tough. There are decided differences in this respect between the massive and the papery shales, the latter sort of shale being mineable, in many places, without any drilling or shooting but simply with picking and shoveling. But our mining activities should be planned to handle massive shale, as a general proposition, and therefore we should prepare accordingly. Massive shale will not probably rend as much from a quick explosion as it will from a slower, crowding one.

There can be no real problems arise in haulage or drainage. These will be of standard requirements. Ventilation will be as in coal mining, with a system of double entries. I do not believe that oil shale will make mine gases to any serious extent, if at all. Whether or not dry oil shale dust will form explosive mixtures with air remains to be learned.

MINING COSTS.

Estimates on the cost of mining oil shale vary widely. We lack much experience which alone can supply close figures. Naturally the mining cost will be more per ton on a 100-ton-per-day basis than on a 500-ton basis. It will be greater in a four-foot seam than in an eight-foot seam. Simply to give you a rough idea on this general item, I will state that various oil shale men have uoted mining costs per ton at from $1 to $2.

CRUSHING.

Some prospective operators include the cost of crushing under the head of mining. To me the crushing expense is chargeable to treatment or milling. Crushing will be done in ordinary types of rock crushers. The fineness to which the shale must be reduced depends upon the retorting process to be used. This fineness ranges anywhere from 80-mesh up to 6 inches. The majority of proposed processes are designed to take shale at about one-half-inch size. When a process calls for pulverized feed, the disc type pulverizers prove adequate. The finer the feed is required to be, the greater will be the cost of this item; but the argument used to offset this fact is that the fine grinding permits a more rapid eduction of the volatiles, thus effecting a lower cost per ton in that item.

In any event, I cannot see any chance for the crushing and grinding cost to exceed a few cents per ton. I would assume that the expense will be about twice as much for pulverizing to say 40-mesh as for reducing simply to one-half-inch size.

RETORTING.

The act of winning oil from the rock is known as eduction. This is more than simple evaporation and condensation. It involves the creation of oil from the kerogen together with the simultaneous removal of that oil by distillation. The eduction of shale oil is comparable to the making of alcohol from corn. There is no alcohol in corn nor is there oil in oil shale. Heat alone can generate either the alcohol or the oil. The process is known as destructive distillation because there occurs the breaking up of original molecules with rearrangements of the atoms into new kinds of molecules: the original kerogen is destroyed.

INTERMITTENT AND CONTINUOUS RETORTS.

Most foreign processes perform the eduction on the batch plan, i. e., they charge, educe and discharge, one lot or batch of shale at a time. The capacity of any such process or retort is limited so that huge batteries or banks of retorts are necessary to obtain reasonably large and continuous outputs. A few American inventions are of this intermittent sort but the majority have been designed to operate continuously.

TYPES OF AMERICAN RETORTS.

There are many distinct types of American oil shale retorts. A person cannot cover their design in any single description. Each kind has a metal, air-tight chamber, of its own particular size and shape, into which the raw shale is charged and within which the oil is generated and converted into vapor. Heating is always external. It may be on all the exterior surfaces, on the bottom only, or on the sides only. The vapors are permitted to escape through orifices in the shell and to pass to forms of condenders that return the vapors to liquid condition.

Attempts have been made to tabulate American oil shale retorts according to shape and operation. It cannot be done with any degree of satisfaction or system. We may say that some retorts are stationary while others rotate or revolve. We may say that some are vertical, others inclined, and still others horizontal. Many are cylindrical, some are rectangular in cross-section, while at least one is nearly hemispherical. Some occupy very small floor space but there are at least two models that are more than 100 feet long in ground plan. In some retorts the shale advances from feed to discharge by gravity; in other retorts the shale travels under mechanical propulsion.

To see one kind of retort gives no notion of their wide variety in shape, size and operation. Each kind undoubtedly indicates its inventor's highest concept of the ideal retort. Of more than 106 such inventions in our country within the past five or six years, probably not more than a score at present show any signs of survival. Publicity is no criterion as to the worth of a process. I know of one very widely advertised process that is a positive fake, used only as a stock-selling exhibit. On the other hand I know of one or two processes that to me possess merit but which are comparatively unknown.

I see no better way to present ideas of oil shale retorts than briefly to describe a few. I shall endeavor to do this impartially. The order in which I shall present these retorts and processes is purely arbitrary and means nothing except that this order will perhaps best bring out the interesting variations in design and practice.

The Jensen retort, a Salt Lake City invention, comprises a series of horizontal cylindrical chambers arranged, one above another, in a vertical tier. The number of such chambers is a multiple of two; usually the number is six. Raw shale, crushed to one-half inch, enters one end of the topmost cylinder and is slowly worked, while being heated, to the opposite end of the cylinder by a screw conveyor. At this further end, the shale drops to the next cylinder through which it travels in the opposite direction. This same treatment continues throughout the rest of the system. Heat for the battery is supplied at the bottom by any desired means, such as solid fuel on a grate, pulverized fuel used with a burner, or fuel oil or gas. All flames and gases of combustion envelop every cylinder on their way to the stack, the entire battery being housed with brickwork. Thus there is an automatic decrease in temperature of these gases as they reach succeeding cylinders from bottom to top. There is one vapor line leading from each pair of consecutive chambers, each such vapor pipe leading to a separate condenser and furnishing its own kind of finished condensate or oil. Mr. Jensen calls this "stage eduction" because the vapors are removed from the shale in stages according to temperatures. An ordinary unit or battery is expected to treat fifty tons of raw shale in 24 hours. Operation is continuous.

The Stalmann retort, also a Salt Lake City device, is an upright frustum of a cone, 18 feet high, 1 foot 6 inches in diameter at the top and 2 feet 3 inches in diameter at the bottom. It is very much like a Scotch retort in this respect and I believe the Stalmann is the American process that shows the closest resemblance to foreign types. The feed is at the top, is continuous and comprises all sizes of mine-run shale up to six inches. Crushing for this process is almost a negligible item of expense. There are no internal moving parts. The rate of progress of the shale downward through the retort is regulated by a sort of turntable device that acts as a discharger at the bottom. Shale is expected to be four hours in passing through the eduction stage. There is but one vapor outlet, this being near the top. Heat is applied on the sides only. Condensation of the single educt from the retort will be by stages or in fractions. A specially designed condenser, made up of numerous concentric cylindrical sheet-metal chambers with intervening chambers that serve as water-jackets, is expected to liquify several grades of oil. The travels of the vapors and the cooling water may be said to be counter-current. The hot vapors entering the central chamber encounter walls behind which is the water that has been heated by its progress through the remaining water-jackets. After delivering a heavy distillate in the first chamber, the vapor proceeds to the next chamber which is annular and herein the next fraction is condensed during the passage of the vapor once around the condenser. Thereafter the process continues, each succeeding distillate being of less specific gravity and of lower condensing temperature.

The Brown retort, a New Jersey invention, comprises three cylindrical steel shells, each 20 feet long, open at both ends. These are placed upon a slight inclination downward from feed to discharge ends. Between adjacent cylinders and at the extreme ends of the retort are cast-iron, hollow, stationary parts into which the ends of the cylinders fit accurately. The cylinders are caused to revolve very slowly, much on the scheme used in certain types of ore roasters, and the shale travels by tumbling. Heat is so regulated as to be progressively greater toward the lower or discharge end. The vapors pass off through ports in the stationary members, but no attempt is made to recover the oil in fractions.

The Wallace retort is a product of the middle west, East St. Louis. It is of intermittent action. Its daily capacity is estimated at 48 tons. This retort is vertical and is oval in horizontal cross-section. It is 14 feet high, 7 feet in long diameter and 15 inches in narrow diameter. Within this shell is another oval shell, this latter being thoroughly perforated with small holes and called the duct. The annular space between these oval shells is 3½ inches and into this space is charged the raw shale. One retort will hold about two tons per charge. Capacity is attained by multiplying these units. Heat is applied upon the outer walls only. All vapors are drawn off as one through the duct, by a slight vacuum. The special claim urged for this process is that the vapors from the shale are withdrawn as fast as made and without passing through any zone of heat that would tend to modify or injure them. Shale is fed at 2½-inch size. The treatment of one charge requires approximately one hour. Only one grade of oil is made.

The Simplex retort is a DeBeque, Colorado, invention. It is an inclined, small metal chamber, rectangular in cross-section, about 12 feet long. For this process the shale is ground to 20-mesh or finer. The feed is at the upper end. The shale is kept agitated on the smooth floor of the retort by numerous rotating scrapers, each attached to a short shaft projecting down through the top. By bevel gearing all these scrapers are driven from one main shaft. Succeeding scrapers rotate in opposite directions and overlap in their travel. The shale passes through the retort in about five minutes. Heat is applied beneath the upper end of the floor and travels downward beneath the floor in the same direction as the shale. This reverses the practice followed in all other types of retorts in which varying temperatures are used externally. The inventors of this retort hold that this plan gives the most intense heat where the shale enters and is coolest and that a much closer regulation of even temperature is thus obtained throughout the length of the treatment. Only one grade of oil is condensed.

The Ginet retort outwardly roughly resembles an ordinary horizontal steam boiler. Shale of half-inch size is fed at one end. Axially through the retort is a strong shaft with numerous arms projecting radially in pairs. Each of these pairs of arms supports a sort of scoop-shovel, about 10 inches broad. As each shovel passes the bottom of the retort in its rotation it scoops up a quantity of the shale and then permits the same shale to slip backward over the rear end as the shovel rises. A deflector on each shovel causes the shale to drop back to the floor of the retort about an inch or two closer to the discharge end. Vapors are taken off through outlets spaced at 9 inches along the top of the shell of the retort. These numerous take-offs lead into one header that delivers one grade of oil to the condenser. The condenser comprises four air-cooled, tall, upright metal cylinders, each containing numerous baffles that require the vapors to travel in a zig-zag manner. Each cylinder collects its own grade of distillate. The capacity is not less than two tons per hour.

The Colorado Continuous Process is the invention of two Denver engineers. The retort is a vertical cast-iron circular tube, the lower end of which is immersed in water as a seal. Lengthwise of the inside of this tube is a special design of screw conveyor driven by gears at the bottom. Shale of half-inch size feeds in continuously at the top while the spent shale is removed from the water at the bottom by a screw conveyor. Discharge pipes for the vapors lead off at various points on the side of the main shell. The vapors pass first through an air-cooled condenser and then through a water-cooled condenser. The fixed gas is handled by an exhauster to the burners of the furnace. One unit will treat from 50 to 75 tons of shale in 24 hours. The retort is housed with brickwork.

The Bishop retort, a Denver man's invention, somewhat resembles a beehive coke-oven. The floor is 16 feet in diameter. The dome is somewhat flatter than a true hemisphere. Heat is applied uniformly beneath the entire area of the iron floor. Centrally of the retort is an upright shaft. From this shaft five sets of arms project radially and carry numerous plows and scrapers. The shaft, arms and plows are of hollow construction for the introduction of steam if desired. Raw shale enters continuously through the center of the roof and is distributed close to the main shaft in a pile several inches deep. As the shaft revolves slowly, the plows act precisely as do those in certain types of ore roasters, causing the shale to spread out in a bed that gradually lessens in depth as it approaches the discharge openings at the circumference. As the spent shale is discharged it drops into so-called annealing chambers within which it remains about two hours before its final rejection. Mr. Bishop states that a small amount of distillation will take place in these chambers due to residual heat. Such vapors will ascend to the main chamber of the retort and pass off with the other vapors, through one main large port in the top. Shale will be crushed to one-inch size. The daily capacity will be 50 to 75 tons. The Bishop condenser will produce distinct fractions of the total oil. The cooling medium will be ordinary air although water sprays may be used. The hot vapors from the retort enter the first compartment of the condenser and make their way through sheet-metal headers and large pipes supplied with internal baffles. There is a counter-flow of the vapors and the cooling air that surrounds the condensing members. By means of partitions, the condenser has eight compartments, each held at its particular temperature, and a separate fraction will liquify in each compartment. A suction fan at the extreme end of the course will assist the vapors in their tortuous travel.

The Galloupe retort, a Denver product, consists of two concentric vertical cast-iron cylinders, each 18 feet high. The outer cylinder, 24 inches in diameter, is stationary. The inner one revolves slowly. The annular space between the cylinders is 3 inches. Upon the exterior of the inner shell and upon the interior of the outer shell are many small horizontal shelves, 2½ inches by 8 inches, arranged like the steps in spiral stairways. Shale of ¼-inch size is fed continuously at the top onto the uppermost shelves. The shelves on the inner or revolving cylinder, being staggered to pass between the succeeding stationary shelves, push the shale from the fixed shelves down to the next shelves. Heat is applied around the outer shell and inside of the inner one, it being adjusted to give the shale a successively greater heat as the shale descends. Takeoffs for the vapors lead from the outer shell every two feet, each such outlet receiving slightly different qualities of oil. In this way there are nine grades of semi-refined oil produced. The spent shale leaves the bottom of the retort through an ingenious air-tight trap and drops while hot onto a special kind of grate where it is used as fuel. The capacity of the retort depends somewhat upon the quality of the shale but will average about 8 or 10 tons per day.

The Chew retort is another Denver product. It is a vertical iron cylinder, 6 feet in diameter and 10 feet high. Concentric within this shell is one that leaves an annular space of about 2 inches near the top and flares slightly toward the bottom. Heat is applied upon the surfaces of both shells. The feed will be of ¾-inch shale, at the top. All vapors will pass off as one through a pump of positive capacity. After traversing the annular space, the shale drops, while hot, into a lower cylinder wherein the residual carbon or coke—the non-volatile parts of the original kerogen—is caused to burn by an induced draft of air, thus supplying the retort with heat. Capacity is estimated at 20 tons per day.

The Ryan process, still another Denver invention but now controlled in New York, is in a class by itself, it being radically different in principle from all other eduction methods. Pulverized shale is fed into a chamber containing a quantity of hot oil known as the bath. This chamber is called the digester. This oil for the bath must be previously prepared so that it will not distil at the temperature used in the process which ranges around 700° F. As new oil is generated by the heat of the bath oil it promptly blends with the bath and then evaporates or distils from the surface and passes to the condenser, as a single product. Heat is applied beneath the digester. It seems a fact that this scheme educes more oil per ton than any other, but mechanical obstacles have thus far held this process in check. The chief trouble is in commercially and economically separating the spent shale from the bath, these two substances forming a stiff sludge. I have been told that it has recently been decided to pass this sludge to some type of continuous still for the recovery of the bath-oil.

I have briefly described eleven processes of which you, as Coloradoans, have probably heard most. I have endeavored to secure drawings or pictures of each kind but the response has been rather disappointing. I attribute the delinquencies to the fact that nearly every one of these processes is as yet, more or less in an experimental stage. There is merit in every one of the processes I have described. Their proprietors are doing their best against financial odds to attain the perfection of the inventions. I wish capital would come forth and do its part in pushing this very vital phase of the new industry.

FIXED GASES.

In most processes there is the generation of considerable gas that cannot be condensed at ordinary temperatures and pressures. This gas is combustible. It is made at the expense or loss of some of the lighter fractions of the total oil. Its production should therefore be reduced to the minimum and this will be a matter of close adjustment of temperature and of quantity of shale treated in a given period.

Some inventors expect their production of this gas to furnish sufficient fuel for their eduction. My view is that any process that yields non-condensible gas in such quantity is inefficient. However, this consideration varies with the operator's choice of marketable products. If he is not desirous for a high recovery of gasoline, but prefers a big production of lubricants, he may be warranted in the generation of much gas. If gas must be the fuel, why not make it from raw shale in a gas-producer? Or why not utilize some of the least valuable oil fractions for fuel?

CRACKING.

Numerous ways have been devised for destroying the molecular structure of the denser fractions of crude oil and reassembling the atoms into lighter fractions, such as gasoline or motor fuel oil. If this kind of treatment could be successfully conducted within an oil shale retort during eduction, so that more gasoline would result without the generation of any considerable quantity of fixed gas, there might be warrant for the practice of cracking. But, in an oil shale retort there is little or no chance to adjust the cracking to this desirable point. The result is that, instead of gasoline being increased in amount, it will actually be lessened by conversion into gas.

Unavoidable cracking in an oil shale retort may result in several ways. If, as nascent oil vapor emerges from the hot shale, it encounters a mass of cooler shale against which it will condense, the chances are that, subsequently, in its re-evaporation, there will occur new arrangements of the atoms into molecules, i. e., cracking will occur. Again, if a vapor does arise from the hot shale without interference but, before it can leave the retort, it condenses against the cooler walls or roof and then drops back onto hot shale, it will probably crack. Also if shale be fed in pieces of such size that considerable time is required to conduct educing heat to their centers, the operator will probably endeavor to hasten his production by carrying an excessive temperature that will crack some of his oil as it is generated.

Eduction Temperatures.

Contrary to common supposition the heat requirements in best treating oil shale are relatively low. To secure the heaviest and least valuable components of the total oil, such as tar, requires a pretty stiff heat. This fact introduces the economic question as to how thorough the eduction should be.

To secure all of the best fractions of total shale oil, disregarding those fractions that solidify at normal temperature, it is unnecessary to heat the charge above 750° F. In fact, a heat of 700° F. is usually sufficient. The walls of the retort itself will require slightly greater heat to overcome non-conduction in the metal, but even so there will ordinarily be no need of heating the walls above 900° F. Since a temperature of about 1000° F. is required to give the faintest tinge of red to metal we see that a proper operating heat will always be so low as to cause no injury to those parts of a retort subjected to the most trying conditions. To completely educe tar, the walls of the retort will require a dull-red heat.

Some shale men think it will be well to leave in the spent shale not only the tar but perhaps some of the other heavy fractions and to utilize these as fuel in the firebox. All spent shale furthermore contains considerable pure carbon or coke that constitutes fuel. When due consideration is given to the phases of this question, commercial practice may not carry the efficiency of eduction above 85 per cent. of the total volatile hydrocarbon.

COMPARISONS OF PETROLEUM AND SHALE OIL.

There are many grades of crude well-oil. Petroleum may have a paraffin base, an asphalt base or a mixed base. The paraffin crude commands the better prices. Shale crude contains some asphalt, the amount of this base depending very materially upon the treatment. Generally, however, shale crude will be classed as paraffin oil. Carefully made shale oil will have a market value in excess of good paraffin petroleum.

There are striking differences between crude petroleum and shale oil in their densities or specific gravities. The same fact holds good concerning their corresponding fractions after refining. The shale oil or corresponding fractions will invariably be the heavier. Thus gasoline may be distilled from both classes of crude by topping up to 300° F. and, although each product has evaporated and condensed at the same heat, their specific gravities may be 20° different on the Beaume scale. This means that the shale gasoline must possess more body or substance. In an engine these two gasolines are bound to vaporize at like temperatures and form explosive mixtures, but they will show different intensities of explosion under identical conditions. The superiority of shale gasoline for automobile fuel has been repeatedly proved.

I have conducted research with refined shale lubricating oils for internal-combustion engines and have found them so much superior to the standard petroleum brands upon the market as to be a class by themselves. While they show greater weight they have higher flash and burning points, they produce much less friction between cylinder walls and pistons, they wear longer and they leave no carbon deposit.

By-Products.

Much is said about many by-products that are obtainable from oil shale. I believe that a few may be produced to good advantage, but I do not advocate their manufacture in the near future. To make these substances will require auxiliary equipment and skilled technical talent. There is plenty of attraction at present in the simple manufacture of a few standard hydrocarbons.

Refining.

Total shale oil may be put through a refining treatment just as is well-oil crude. Standard refining practices will be quickly adapted to shale-oil treatment. This refining will cover both the splitting of the crude into fractions and the purification of those fractions.

If an oil shale eduction plant produces total oil only and there is no refining equipment, the crude must be sold to custom refiners at a barrel rate. But whenever an oil shale plant of any considerable capacity is erected it should include full refining equipment that will turn out finished marketable products.

When an eduction process produces fractions, their marketability will depend upon their purity and their standardization. Fractions resulting from the escape of vapors through several outlets in a single eduction chamber cannot be expected to be as distinct as are those fractions made from vapors emanating from several chambers of differing temperatures.

Every liquid has its fixed temperature of evaporation or distillation. Its vapor will return to liquid at precisely that same temperature. Fractional condensation takes advantage of this scientific fact and is simply a reversal of standard fractional distillation as practiced in refineries of petroleum. It accomplishes fractionation without any secondary heating and requires much simpler apparatus.

USE OF STEAM.

Most authorities advise the admission of steam during eduction. There are at least four good reasons assigned:

1. An amount of steam blown into a charge of hot shale produces a rapid migration of the evolving vapors so that they are quickly swept out through the exits before they can become damaged. Such steam must be of a temperature not less than that of the vapors. Steam in this sense is a sort of scavenger.
2. A moderate quantity of superheated steam assists greatly in disseminating a uniform temperature throughout the retort.
3. If the manufacture of ammonia is sought the yield will be appreciably increased by using steam.
4. It is held that superheated steam coming in contact with hot atomic carbon will partially react into carbon monoxide and hydrogen and that the nascent hydrogen will combine with the carbon to make hydrocarbons, thus increasing the total yield of saturated oil.

Of course every pound of steam fed into the retort means that extra weight of water to be handled in the condensing and storage systems. And, speaking of water, no matter how dusty and dry a raw shale may be, its distillate will include a good percentage of water, this being the structural water of the rock itself.

TOTAL OPERATING COSTS.

I have said a word about mining costs. The expense of eduction and refining will vary greatly with processes. It will be more when auxiliary refining is done than when fractional condensation is followed.

The big profits in the oil industry are made by the refiners. Every oil shale company of pretentions should equip to do its own refining and reap the financial benefits. Crude shale oil that might not bring more than $4 or $5 per barrel may be refined into products having a combined wholesale or jobbing value up to $15.

I have given much thought to operating costs. I find them to vary widely for different processes and capacities. I will give you a few figures that I believe represent average conditions, covering mining, milling, marketing, overheads and contingencies:

For 100-ton capacity,	$4.92 per barrel of oil.
For 500-ton capacity,	2.61 per barrel of oil.
For 1000-ton capacity,	2.35 per barrel of oil.

These figures must not be assumed to apply to all processes nor to any one in particular. They are rough averages for those processes that practice fractional condensation. They are based upon the recovery of but 35 gallons of oil per ton instead of the customary 42 gallons.

Assuming that the total oil will yield 15 per cent straight-run gasoline salable at 20 cents per gallon and that all the other fractions will go into flotation and other oils and various grades of lubricants, all of which will command wholesale prices not less than 50 cents per gallon, the income per ton will be $15.92. For different capacities the excess of income over cost will be:

100-ton plant,	$12.52 per ton.
500-ton plant,	14.45 per ton.
1000-ton plant,	14.67 per ton.

Investment Charges.

From what has been said heretofore as to the wide variety of eduction processes and methods of producing marketable products, it will be evident that I cannot give accurate figures for the cost of any complete oil shale installation without knowing exactly the process to be used. In any event the investment is not small. Nobody should expect it to be small. This is a manufacturing proposition of stated capacity and it is installed to operate continually at that capacity with its corresponding production. It is a straight industrial. If a plant is erected to produce 500 barrels of oil per day, it will keep up that production indefinitely: there will be no depletion as in petroleum experiences.

In an effort to give figures on this matter of investment for plant, I have collected data that I consider reliable and of an average. If anything, my figures are low as to investment charges. They include equipments for mining, milling and marketing:

100 tons per day, $151,216; annual depreciation, $16,882.
500 tons per day, 458,192; annual depreciation, 54,019.
1000 tons per day, 875,890; annual depreciation, 103,589.

The oil shale industry is not a game for small operators. It is a big thing. The investment for land and equipment is no greater, however, than it is for any other kind of an industrial or manufacturing business of like magnitude. By this I mean that for equivalent financial returns, an oil shale business is no more costly to install and operate than is a sugar factory or a cement works.

In Conclusion.

I presume I will be accused of being unduly optimistic about this infant industry. I admit my intense interest in it and my faith in its future. I do not, however, carry my notions beyond rational bounds, I trust. I would not have it understood, for instance, that success will attend every installation during the next few years, and for many reasons which are not alone of a mechanical nature. I see in this industry the need of strict attention to scientific practice and I do not predict success for any company that disregards this feature. Men of former experience in this work are indeed scarce. I do not feel that they can be secured even from the Scottish oil shale field since our operations must be totally different.

This creates a splendid field for our technically educated youths and I trust that the older men who may have had experience will not be selfish in passing their knowledge of eduction on to these young men.

I have never attempted to invent a process. I have cooperated with as many inventors as I could keep in touch with, in an earnest desire to assist them to full demonstrations of their processes. They have all aided me in a fuller comprehension of the technique of the industry and I am glad to acknowledge their friendship.

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VITAMINES

By Carroll E. Edson, A.M., M.D.

(Read at the meeting of the Society, October 1, 1921)

During the last decade no subjects connected with the fundamental medical sciences have received more attention than the group of so-called deficiency diseases, and the nature and distribution of the nutritive substances involved in their cure and prevention. The importance to normal growth and health of the undetermined substances, which for the present we call vitamines, has been fully established. The role which these alimentary factors play in normal nutrition has been studied with increasing interest, as their wide and far-reaching biochemical relationships have been appreciated.

You will perhaps follow the technical portion of my paper more easily if I give you first an illustration of what we mean when we speak of a deficiency disease; and then relate briefly the sequence of investigations which led to the discovery of these still unknown substances. It will be interesting to see how the study of a disease caused by the lack of a definite substance in the diet led not only to our first knowledge of the existence of that substance, but to an appreciation of previously unrecognized but essential factors in normal nutrition.

You will recall the terrible sufferings from scurvy from reading the accounts of the voyages of Arctic explorers and early maritime adventures, and how whole crews perished from inability to man their vessels when weakened by the disease. The scourge, you remember, would break out after a long continued diet of salt meat and hard bread, and was cured promptly if the men could be given fresh, raw vegetables. In the absence of such green foods—impossible to carry on long voyages—it was found that lemon juice added to the diet would prevent the development of the disease. As far back as 1795 the British Admiralty required and regulated the issuance of a ration of lemon or lime juice, as it was called, to the crews of all ships in the navy and merchant marine.

Here was a typical deficiency disease. It was not so called at that time, for the term is of very recent coinage, and the cause of the disease was variously explained. The empirical cure by fresh vegetables and lime juice preceded by a century our understanding of the true nature of their action. I will return to this latter in my paper.

Now, for the way in which these substances were discovered.

Beri-beri is a disease more or less common in tropical and subtropical climates, especially in the Far East. It is characterized by a general widespread inflammation of the nerves, a multiple neuritis, as we call it, with paralysis, great weakness, especially of the heart muscles, some oedema or dropsy, and liability to sudden death from heart failure. It was formerly very prevalent in the Japanese Navy, being one of the chief causes of disability. After 1884 it was materially lessened following an improvement in the ration. During the Russo-Japanese war, there were over 150,000 cases in the Japanese army. The cause was variously attributed to infections, bacterial or toxic or chemical, as well as to dietary conditions, since it was more common among the poor and those living wholly on rice.

In 1897 Eijkman, experimenting on pigeons and poultry, found that a condition of avian polyneuritis wholly comparable to human beri-beri could be induced by feeding the fowls a diet restricted to polished rice; and that this condition did not occur in birds fed on the whole or unpolished grains. Some substance in the germ, or the aleurone layer of the pericarp was essential to prevent the development of the polyneuritis; for the addition of the polishings to the diet promptly restored the health of pigeons suffering from the induced disease.

Vordeman in 1895-96 showed that the prevalence of beri-beri in the military prisons of Java was directly in proportion to the use of polished rice as a diet, and could be prevented by the use of unmilled grain.

In 1909 Fraser and Stanton proved conclusively by carefully controlled experiments in rationing laborers in the Malay peninsula, that beri-beri could be absolutely prevented by the use of rice not deprived of its aleurone layer, and equally surely induced under identical conditions of housing and labor, if the men were fed polished rice. An economic point of some interest lies in the fact that the exclusive use of the fully polished rice and the consequent increase of beri-beri among the poor followed the adoption of modern American milling machinery.

In 1910 Casimir Funk, in an elaborate study, showed that this protecting substance could be extracted from rice polishings by alcohol and that so small a dose as two milligrams would promptly restore to health a pigeon dying from induced avian polyneuritis. So potent indeed was this extract that a bird unable to move or even to stand would in an hour after receiving it begin to eat and walk, and in a few days be apparently as well as ever. The alimentary factor while indispensable, was required in but small amounts.

He proposed the name vitamine for this substance on the supposition that it was of the nature of a nitrogen base like the amines. He suggested by analogy that there might be several such substances, each specific for one of the various diseases, such as scurvy, rickets, and pallagra, which might be caused by an absence or deficiency of this vitamine in the diet. This suggestion though made without any experimental proof was one easily adopted, and had much to do with the general acceptance of the name vitamines for all these unknown substances.

The stimulus of Funk's publication led to research in experimental nutrition along new lines. The work of Osborne and Mendel, Hopkins, McCollum, and a host of others speedily showed that our earlier conception of nutrition was incomplete; that the caloric balance alone was not the whole problem, that in addition to the proteid, carbohydrates, fat and mineral content of the diet, other factors, "accessory food substances," Hopkins called them, were necessary for life and development.

Van Leersum in a recent most interesting review, called attention to the fact that so long ago as 1905 Pekelharing, a Dutch physiologist, anticipated the work of Hopkins in experimental diet and suggested that there might be some such factors concerned in the problem of nutrition. Pekelharing's paper was published in Dutch, which at that time was not widely read. His idea, therefore, fell on barren ground.

The basic advance made by these later investigators was in carrying out their feeding experiments with chemically pure or strictly isolated proteins, carbohydrates and fats. By this means they proved that a diet of such proteids, starch, fat and mineral salts though varied, in right proportion and of ample caloric total, was incapable of sustaining life beyond a very short time; less in some instances than the life of a control animal deprived of all food. If, however, these different components were supplied in a natural state, or there were added to the artificial diet a portion only of such natural ingredients, as for instance, butter fat in place of vegetable oil, or whole grains and green vegetables to replace the pure starch, the animal lived and throve. If the percentage of this natural food were too small, the animal might live or maintain its weight, but it would not grow, mate or reproduce.

It was apparent that to maintain life, health, and normal growth the diet must contain at least two other unknown substances. These, from the medium with which it was found they could be extracted from natural foods, McCollum proposed to call fat soluble A and water soluble B until their exact nature could be determined.

Until 1914 these investigations had been of interest, as matters of pure science, chiefly to students of biochemistry. For the reason that the ordinary natural diet of human beings contains a sufficiency of all these substances, their existence and the vital necessity of their presence in the food was not recognized by physiologists and dieticians. In the exceptional cases, and unusual degrees of poverty, the effect of the lack of these factors was obscured by and confused with the general caloric deficiency.

With the continuance of the war against Germany, the question of food supply became a very real and practical matter. The need for making the diminished ration count to the uttermost in maintaining health became a pressing and absorbing one to individuals and governments. The whole world became aware of the need of animal fats. We were furnished a human experiment on an enormous scale to try out the facts slowly gathered in the laboratory from studies on pigeons, rats, and guinea pigs. It was this human test which brought the subject to general attention.

Since 1914 the scientific literature dealing with vitamines has grown to forbidding volume. Not a little theorizing has been put forth, deduced from uncontrolled observations, but gradually the definite relations of these substances are becoming understood and their influence on individual and national health can be gauged.

After this rather lengthy introduction, I will present briefly and without argument such facts concerning these vitamines as are now established. The shortness of time will oblige me to omit many interesting experimental details and to deal only with those which have already an applied interest. It must also excuse the dogmatic form of statement.

First, some general facts:

These unknown substances, called vitamines for short, are all present in natural foods, though in varying amounts and in different distribution.

They have this characteristic in common, that they are intimately associated with the natural state or freshness of the food substance.

They are destroyed, lessened in amount, or deteriorated in quality by various mechanical or physio-chemical treatments associated with artificial preservation or culinary preparation.

They are not tissue builders like proteids.

They are not energy producers like carbohydrates.

We know nothing of the mechanism of their specific internal role.

They appear to act, as do catalysts, to enable proteid and carbohydrate metabolism to carry on. As one writer puts it, they supply "the will to metabolism."

They are necessary only in small amounts, but this minimum is definite and irreducible—three per cent in the case of fat soluble A.

They have not yet been isolated chemically and we do not know their structure. It is possible that the water soluble B is of the nature of a nitrogen containing base. It was this reason which led Funk to give it the name vitamine. Late study has shown that they are not amines, and the fat soluble A contains no nitrogen atom at all.

They are of varying stability; destroyed by heat of over 130° C., or by lower temperatures if prolonged; the degree of destruction being in some instances directly proportional to the duration of exposure to the high temperature.

They are damaged by alkalies, and particularly by oxidation in the presence of heat or alkalies. Foods deteriorate in their vitamine content by long keeping or other conditions which we associate with age or staleness. The vitamines are thus connected with that quality of naturalness which we call freshness and life.

They vary in amount in different foods and greatly in different specimens of the same food, according to circumstances. This latter variation is of great interest and no small importance as will be shown later.

From this general description of the group as a whole, let us pass to each of the types in turn, studying briefly its qualities, distribution, and nutritive influence.

Fat soluble A is the name now commonly given to the unidentified substance which is essential to nutrition, development and reproduction. Animals fed on a diet ample and varied, except that it is devoid of this substance, maintain their nutrition for a short time only. After about ten days they begin to lose weight, then a little later refuse to eat, and, in the case of rats or guinea pigs, invariably die in from thirty to fifty days. If fed a diet containing a small but insufficient amount, they may hold their weight, but do not grow and fail to mate or reproduce. After a fortnight there develops a condition known as keratomalacia, a disease which begins with slight haziness of the cornea and rapidly progresses to softening, rupture, and loss of the eye. Bloch reports a similar condition in the eyes of children in Denmark when deprived of butter fats, and McCarrison states that it is common in parts of India where the diet is notoriously deficient in foods containing this vitamine.

This substance, *fat soluble A*, is not abundant in nature and is found most generously in the butter fat of milk, and in the yolk of egg. It is present, though to a less degree, in other animal tissues, most richly in the glandular organs like the liver or kidney, and in the fat tissues except lard. It is scanty in the muscular tissues commonly used as meats. It is wholly absent from vegetable fats and oils and from cane and milk sugars. It is found plentifully in the green leafy parts of vegetables such as spinach, lettuce, cabbage, parsley, celery, and dandelion. In the seeds of grains it is scanty and is found only in the aleurone layer, and not in the endosperm. It is therefore lacking in bolted wheat, degerminated corn and polished rice. Peas, lentils, whole wheat, corn, oats, rye, barley, and beans contain it, but not in sufficient amount to supply the whole need. It appears to be associated in some way with the yellow pigment in certain vegetables and is more abundant in young carrots than in old, in yellow corn than in white, while red corn stands between the two in content value.

It is thermostable to ordinary degrees of heat, but destroyed by oxidation or mechanical agitation while heated, or by dehydration. Ordinary household Pasteurization does not destroy it, if the milk is used promptly. Commercialized Pasteurization, which is frequently accompanied by much mechanical agitation and oxidizing agents or conditions, does injure it. The destructive action of high or prolonged heat explains the lessened nutritive value of overdone lean meat and of renovated butter.

The absence of the vitamine from all vegetable oils points a caution against the sole use of the substitute fats and hydrogenized vegetable oils in place of the natural butter fat of milk. It is the vital need of this *fat soluble A* to maintain nutrition which makes indispensable the feeding of animal fats to the growing child.

About three per cent of a vitamine-A-containing fat must be included in the diet for full nutrition. In so far as the diet is deficient in this substance the child fails to be nourished and is less resistant to infection and disease. The practical bearing of these facts is obvious. The nursling has in breast milk and fresh cow's milk an adequate amount. The growing child must have for its full development an ample supply, which is most readily found in milk, butter fat, and eggs. The green vegetables and whole grains will furnish a considerable measure of the *fat soluble A,* but not to exceed one-half the ration needed.

The question of the relation of the fat soluble vitamine to rickets has not been fully settled. That the disturbance in calcium metabolism seen in this disease is in some way related to that of the fats; and that cod liver oil (rich in *fat soluble A*) is a direct re-establisher of the normal metabolism, are beyond doubt. Other factors of hygiene and nutrition are not yet to be eliminated. We are not justified in saying that rickets is due solely to a lack of the *fat soluble A*, nor can we assume the existence of a specific antirachitic vitamine for this disease. Whether we may ultimately find this unknown substance to be one or several, it is too soon to say. The conditions under which rickets usually develops certainly suggests that a nutritional deficiency of some sort is an etiologic factor. That it is a specific deficiency disease, as is beri-beri, is not finally established.

Lambert calls attention to the extreme rarity of rickets in Turkey and Syria before the war; though many cases were seen during and since the war among refugee children.

The second undetermined constituent of food essential to health is the *water soluble B,* or antineuritic vitamine, as it was originally called when its absence from the diet was shown to be the cause of beri-beri and avian polyneuritis.

It is widely distributed in all natural foods. It is abundant in all green and leafy vegetables such as spinach, lettuce, cabbage, celery, and dandelion; in potatoes, carrots, turnips, onions, tomatoes, and in the tops of beets, not the root. It is very abundant in alfalfa, clover, timothy, and in Kaffir corn and millet. It is present in milk, eggs, and the animal tissues used as food, except that it is not found in animal fats or butter fat. It is absent also from all the vegetable oils, from syrup, cane sugar, and milk sugar.

In seeds such as peas and beans there is from three to six times the amount necessary to maintain health. In grains it is abundant, but exists only in the aleurone layer, and so is absent from polished rice, bolted flour, and starch. Brewers' yeast is rich in this *water soluble B;* bakers' yeast less so, but yeast grown on synthetic media will not have fermenting power unless there has been added to the medium some mesure of organic material known to be rich in vitamines.

The wide distribution and generous measure of this substance in so many natural foods assures its sufficiency in all ordinary diets. Its absence in a degree to cause disease can occur only in the very poorest people whose diet is extremely limited to starches, such as polished rice, and sugar or glucose.

The *water soluble B* is thermostable to temperatures of 100° C., and its destruction by higher temperatures is proportional to the time of exposure to the heat and to the presence of alkalis in the water. For instance, the vitamines present in wheat embryo, curative for experimental polyneuritis in pigeons, is stable at temperatures of 100° to 104° C. for one or two hours. After being subjected to a temperature of 120° for one hour, the dose must be doubled to be effective. After two hours at this temperature the dose must be quadrupled.

One practical deduction from this fact is to caution against the exclusive use of canned foods. The higher degree of heat used in the preparation and the longer period elapsing before consumption may cause deterioration of the vitamine content. A diet composed largely of such foods, if long continued unsupplemented by fresh food stuffs, may prove detrimental to health. Except under such conditions of poverty or grossly improper dietary as to be obvious, the *water soluble B* is never lacking in our meals, nor does it need especial attention.

Lastly, a most interesting fact. The vitamines are apparently not formed in the animal tissues, but are stored there from the vegetable foods ingested. This is especially true of the *fat soluble A,* which is not synthetized by the animal body at all. Its presence in the butter fat of cows' milk is dependent upon, and in seeming proportion to, the richness of its content in the fodder of the animal. Milk from cows, stall fed in winter, is much less rich in vitamines, both A and B, than that from the same cow when on spring and summer pasturage, with abundant leafy green food. So we see that the quality of milk is a factor not entirely measured by the casein and fat analysis. Careful feeding experiments at the Wisconsin Agricultural College have shown beyond question that the vitamine content of the fodder of cows had a direct and constant influence on the growth, weight, and breeding development of the calves.

Similarly babies may fail to obtain a sufficient amount of vitamines from breast milk, if the mother is starved of these factors in her own diet, as in time of famine. This was amply proved in Vienna after the war by Chick and Dalyell of the British Relief Commission. They found for instance a marked improvement in growth and development of a breast-fed child, after adding thirty grams of turnip juice and fifty grams of butter to the mother's diet, although there was no increase in the amount of milk secreted by the mother.

When we think of this close vitamine relationship and interdependence of child and mother, and cattle, and the very herbs of the field, surely the thread of life runs far. We can say with the Buddist "ascending or descending, all are bound on the wheel together."

So far most of the research on the vitamines in various foods has necessarily been limited to determining their presence or absence. Enough data are accumulating, however, to show that the quantity present is most variable and a matter of some importance. Until we know the chemical structure of the vitamines, quantitative analyses of foods for these substances is impossible. The labor of determining the measure of their presence by finding experimentally the minimum amount of each food which will protect is far too great to permit of any progress in tabulation, especially when we recall the fact that different samples of the same kind of food vary in vitamine content with the soil on which they grow.

Now, to return for a moment to the scurvy with which we began. The usefulness of potatoes, especially when germinating, fruits, and tomatoes as a preventative and cure had been proved in Arctic and military expeditions. It was made notably evident in the Mesopotamia campaign of the great war.

The study of vitamines and their relation to deficiency diseases in the last decade has stimulated new research into the biochemistry of scurvy, and the substance necessary to its control. This antiscorbutic vitamine, now called *water soluble C*, to group it with others, is present most abundantly in the citrus fruit juices and in tomatoes. It is also found in the juices of raw turnip and cabbage, as well as potatoes and to some extent onions. It is present in orange peel in which it withstands drying. One peculiarity of the *water soluble C* in tomatoes is that this variety (if we may make use of the term) withstands a much higher temperature than any other form. It is this thermostability which makes tomatoes so valuable a canned vegetable for distant carriage and long preservation.

The development of a form of infantile scurvy in babies fed on artificial foods has been generally recognized during recent years and you are all doubtless familiar with the use of orange juice for such babies.

Among adults it becomees a problem of importance only in the rationing of large numbers under conditions of famine, army maneuvers, long voyages, prison or almshouse life.

The interesting fact to bring to your attention tonight is that recent work suggests that we may soon have the means of knowing the chemical composition of this antiscorbutic vitamine. In the August, 1921, number of the *Military Surgeon*, Lieut. Col. Vedder of the Medical Corps U. S. Army, reports some very careful experiments in which he has determined the solubility, absorption, and precipitation differences of the antiscorbutic and antineuritic vitaliments, which is the new name he proposes for them.

I quote his conclusions:

"1. Scurvy can be produced in guinea pigs with regularity by feeding a liberal and varied diet consisting of oats, mixed scratch feed, bread, sterilized milk, and hay.

"2. Scurvy may be prevented by the daily addition of five grams of green grass or five c.c. of filtered orange, lemon or grape fruit juice; and cured by larger amounts.

"3. The antiscorbutic vitaliment is soluble in water, absolute alcohol, acetone, and commercial ethylacetate.

"4. The antiscorbutic vitaliment cannot be extracted from the partially dried juice by either chloroform or carbon-tetrachloride.

"5. The antiscorbutic vitaliment differs from the beri-beri or antineuritic, preventing vitaliment in the following particulars:

A. The antineuritic vitaliment is absorbed by finely powdered animal charcoal. The antiscorbutic vitaliment is not so absorbed. (Harden and Zilva, confirmed by the writer.)

B. The antineuritic vitaliment is precipitated by phosphotungstic acid. The antiscorbutic vitaliment is not so precipitated, but is probably destroyed.

C. The antineuritic vitaliment is a nitragenous base The anti-scorbutic vitaliment is apparently non-nitrogenous.

"6. By means of the solvents mentioned above, a purified extract has been prepared which is suitable for further chemical study."

If this prove true, it is the first step toward the isolation and exact knowledge of the structure of all these substances.

Lambert in a report on the post-war medical conditions among Armenian refugees in southern Turkey and Syria (*Military Surgeon,* September, 1921) remarks that while the majority of the refugees arriving at Aleppo were poorly nourished and more or less anaemic, there were no examples of special dietary deficiency; that they observed no cases of the common deficiency diseases such as scurvy, beri-beri, or pellagra. Yet the average refugee had subsisted mainly on bread, made from whole wheat, and raw vegetables.

Olive oil normally enters largely into the diet of the people of the near East. During the war there was a shortage of the product in many districts, owing to the use of olive trees for fuel and the interruption of trade. The rapid improvement in cases among refugee children placed on the normal oil-rich diet was very striking. So far as yet determined olive oil contains no *fat soluble A.*

Pellagra is the last of the diseases which we are justified in classifying in the deficiency group. Its nutritional etiology is still under dispute. The amount and quality of the proteid content of the diet is unquestionably one factor in its causation or cure. We cannot, however, allign it under any one of the present known vitamines.

Commercialism and quackery have followed their usual course, promptly exploiting the newest theories of science to their own profit. It is this advertising propaganda which is largely responsible for popular interest in the subject. The brief resumé of facts which I have given may help you to correct the scientific misconceptions of the intelligent and refute the ridiculous claims of the commercial nostrum vendor. In daily life we have this concern only with vitamines: to see that babies have a sufficient amount of good fresh milk and that growing children receive with their food plenty of butter fat, some fresh vegetables, and fruit. From such ordinary diet they will obtain all the vitamines they require.

In the case of adults, deficiency can occur only in obviously and grossly imperfect diets and the need can be met easily by simple, rational regulation of the food.

There is no occasion whatever to employ extraneous and commercially exploited preparations, whether of yeast or any other supposed vitamines. You must not allow yourselves to be deluded by pseudo-scientific language or deceived by false and impossible claims for these proprietary outputs.

Remember that vitamines are not tissue builders: they are not energy producers: they are not precreative rejuvenators. They are essences necessary to nutrition and health, but they are present in abundance and full sufficiency in normal natural food, if that be given in proper amount and variation in a fresh undamaged state. The addition of supposedly artificial preparations of these still unisolated substances to a diet containing the sufficiency found in normal food, will not increase growth, weight, vitality, health, or beauty.

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CONCRETE PAVEMENTS

By Lt. Col. H. C. Boyden
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(Read at the meeting of the Society, October 29, 1921)

During the last decade the use of concrete for the paving of highways, streets and alleys had increased consistently all over the United States and Canada and there is every reason to believe that the increase in use will be much more rapid in the next decade.

At the beginning of the year of 1909 there had been built in the U. S. a yardage of unprotected concrete pavements which was equivalent to the following mileage: 3·2 miles of 18′ highway, 19·0 miles of 40′ streets and 12 miles of 16′ alleys. At the present time (October, 1921) only 13 years later, there has been built or placed under contract a yardage equivalent to 17,067 miles of 18′ highway, 2,663 miles of 40′ streets and 782 miles of 16′ alleys. When we plot the yardage curves by years we find two noticeable facts. The rapid upward trend of the curves began in 1914 and continued at about the same rate until 1919, and then the highway and street yardage curves increased each year over two and one-half times the yearly rate of the previous five years.

This rate of increase shows every sign of not only continuing, but of still further increasing each year. The yardage of alley pavement has not shown the same phenomenal increase as have street and highway pavements, but there has been a steady, constant gain each year and this will undoubtedly show a decided rise as concrete for city pavements comes more and more into use.

The second fact noticed in studying the curves is that considerable more yardage has been built or placed under contract since January, 1919, than had been built in all the time previous to that date, or an increase from 113,555,152 square yards to over 250 million square yards today.

Attention is called to the fact that the above figures do not take into account the immense yardage of concrete bases with various types of wearing surface on top, but only includes unprotected pavements where the traffic operates directly on the concrete. The yardage of such bases is very large and nearly all pavements being built in our cities today include a concrete base.

The rapid increase in the last three years can be accounted for in many ways, but there are two things that have probably done more to bring it about than all the other factors put together. The first is the steadily growing confidence on the part of both engineers and laymen in the ability of this type of pavement to give the greatest amount of service for the least cost. The second fact is the rapid acquirement on the part of engineers and constructors of the proper methods of design and construction and of the fundamentals and process to be observed in obtaining good concrete.

Back of these two facts may be seen the steady, consistent, promotional and educational work done by the forces of the Portland Cement Association and the exhaustive research work done by Prof. Duff A. Abrams at the Structural Materials Research Laboratory carried on through the cooperation of the Association and the Lewis Institute at Chicago.

This phenomenal growth of the use of concrete for pavements makes it very necessary that these pavements shall be built right in order that there may be no, or at least a minimum amount of, failures and that the confidence of the people may be justified.

It is with this necessity in view that this paper will endeavor to outline as many of the correct principles to be followed in construction and the making of the concrete as the time allowed will permit.

The success of any type of pavement is absolutely dependent upon the foundation upon which it is laid and too much emphasis cannot be put upon the necessity for exercising the greatest care in studying the existing conditions, designing and building the drainage system and in building up and making a uniform subgrade.

The unfortunate fact remains, however, that in spite of all that has been written on this vital subject and in spite of the realization of its importance by all engineers, more road and street surface failures have been caused by improperly built sub-grades than by any other one phase of construction. There are many causes that contribute to ununiformity in the bearing power of sub-grades. The principal causes being poorly designed drainage or often-times lack of any drainage, insufficient rolling of some soils or excessive rolling of other soils, insufficient scarification of existing macadam or gravel road surfaces, often-times leaving at the sides, in cities, old water pipe or sewer trenches which have been improperly filled in, and last but by no means least, the constantly varying classes of materials encountered in the progress of the work.

Several different classes of materials often occur in less than half a mile of construction, each one of them requiring a different kind of treatment to give it the same bearing power, and yet in the process of grading they may be so mixed up that they receive practically the same treatment when the sub-grade is being finished.

With these contributing causes, it is no wonder that soft areas and hard areas occur in sub-grades, sometimes small and sometimes large in extent and often-times close together. In view of this fact, it is absolutely necessary, in order to prevent uneven surface conditions from developing, that the pavement be so constructed as to have sufficient slab strength to bridge over areas, which have less supporting power than adjacent areas.

Because of these facts, too much care cannot be taken in the preparation of the sub-grade in order to make it as nearly uniform as is possible. Uniformity in bearing power is to be desired above all, and there have been many cases where the sub-grade has been soft but uniform and excellent results with the pavements have been obtained. Should the material forming the sub-grade be heavy clay, gumboe or adobe, care should be taken to avoid excessive rolling and a layer of pervious material not over six inches thick should be spread on before laying the concrete. This previous layer should be sealed on top with a thin layer of impervious material to prevent the rapid absorption of moisture from the bottom of the slab and a consequent weakening of that portion.

With regards to the width and thickness of concrete pavements, it is not possible to go into a thorough discussion, but only to outline a few of the fundamentals. The minimum width for a highway should be 18 feet, and there is a tendency to increase this to 20 feet in many sections of the country. This is particularly noticeable where narrow and thin concrete roads are being thickened and the new width is being made 20 feet. As the traffic on our highways increases both in volume and size, the need for wider pavements than 18 feet increases.

One great reason for this additional width is the fact that the shoulders, especially on fills, are seldom made of proper width and are seldom kept level with the surface of the pavement. Due to this fact, the driver of a machine, whether it be a heavy truck going at a slow rate of speed or a light machine traveling fast, hesitates to run on the extreme edge of the pavement, and consequently the outside foot of the width is seldom used. This cuts the effective width down by two feet and gives us much less passing space than is often-times safe.

If the shoulders on all roads could be kept high and wide enough and they were made of materials suitable to carry the loads of occasional passing vehicles under all weather conditions, the effective width of all pavements would be increased. It is an unfortunate fact that they are seldom maintained even when originally properly constructed and for that reason 20 feet is more advisable than 18 feet.

The question of thickness of a pavement is one that admits of a great deal of discussion and, when all is said, we must at the present time fall back on practice, experience and personal judgment. There is one fact, however, that must be looked squarely in the face, and that is the constant tendency of all highway traffic to heavier unit loads. If we are to build pavements with a reasonable expectation of at least twenty years' service we must take this fact into consideration and build accordingly. Because of this fact it is not advisable to build less than eight-inch pavements for highways and business districts in towns and cities, and under no conditions less than six inches thick. Where a flat sub-grade is used, it is the custom to reduce the thickness at the sides by the amount allowed for the crown, but it is a question whether this is advisable in view of the fact that the bulk of the traffic travels on the edge of the pavement.

In many sections where the roads are subjected to heavy truck traffic, surfaces are being built nine and ten inches in thickness, and it is believed that this practice will become more and more common as the need becomes more apparent.

The practice of reinforcing concrete pavements is one of personal opinion, and there are many arguments both for and against. There is no question that reinforcing has many advantages, especially where the sub-grade conditions are poor, but under no conditions should the thickness of the slab be reduced with the idea that the thinner reinforced slab will be of equivalent strength.

Reinforcement, in the amounts commonly used (thirty to sixty pounds per square) will not entirely prevent cracks, but will serve to hold cracks together. Both wire mesh and rods are used for reinforcing slabs, but the general tendency is towards the latter, placing them about two inches from the surface. Rods or mesh so placed do no add materially to the slab or beam strength of the pavement and consequently should never be used to replace thickness.

Expansion joints are being used or not according to the individual ideas of the engineers in charge of the work and have both advantages and disadvantages. The joints, when used, should be composed of a fibre matrix prepared with bitumen, placed not over thirty feet apart, and great care should be used to see that they are kept straight and at right angles to the surface of the pavement. A joint which is not at right angles to the pavement is very likely to allow one slab to slip or rise when expansion takes place.

One of the great objections to expansion joints is the tendency found so many times of allowing the concrete to pile up at the joint and cause an uneven riding surface. This can be prevented, providing care is taken and a long straight edge (not less than 10 feet) is used parallel to the axis of the road.

The use of armoured or concealed joints is not recommended. A slight rounding of the edges of the joints with a tool having a radius of not over three-eighths inch is often done with very effective results, as it prevents the slight chipping which sometimes occurs. For the same reason it is quite often the custom to round the edges of the pavement, using a tool with slightly larger radius.

It is very often necessary either to start work or finish a section of road during cold weather, and when this is done, care must be taken to prevent the freezing of the concrete.

The hardening or setting of concrete is a chemical action which takes place between the cement and the water used in mixing. When the concrete freezes this action is stopped and we have a case of suspended animation. Owing to the fact that when water freezes it expands, freezing and thawing will destroy concrete. If, however, the concrete freezes while it is still plastic (thereby preventing harm from the expansion of the water) and remains frozen until it thaws out in the spring, it will not be damaged. The process of hardening will not go on while the concrete is frozen but will immediately begin to take place as soon as the concrete thaws out.

In spite of the above facts, concrete pavements should be prevented from freezing by the exercise of proper care. When the temperature during the middle of the day falls below 40 degrees it is time to take precautions against freezing during the night, and it is often advisable to heat the ingredients. The heating of the ingredients is done in order to accelerate the hardening of the concrete and thereby overcome the possible effect of low temperature during the night.

When the temperature of concrete falls below normal (70 degrees) the hardening process begins to be retarded, and between 32 and 40 degrees it takes place very slowly indeed. Because of this, when the temperature remains consistently at 40 degrees or below, the concrete will harden very slowly and artificial means should be employed to raise the temperature.

In mixing, the water, sand and stone may be heated, and canvas covers should be placed over the paving in such a manner as to allow heating of the enclosed space. The heating of the ingredients is done in a variety of ways, by use of fires under semi-circular iron tunnels and by the use of live steam. The latter method is the most common and has the advantage of being free from the danger of overheating the sand and stone or pebbles. Some classes of materials will break down under temperatures of over 250 degrees and will be rendered unfit for use in concrete.

It would not be advisable to have the temperature of the mixed concrete over 90 degrees, as temperatures above this point are likely to be harmful. There are many methods used for heating the canvas enclosures over concrete, such as using salamanders, stoves and live steam. Live steam is believed to be the safest and most effective as it can be more evenly distributed by frequent valves in the pipes, and due to the fact that the heat is moist.

When stoves or salamanders are used, care should be taken to prevent excessive heat in areas near them which will cause uneven drying out of the pavement.

The use of salt or sodium chloride to lower the freezing point of concrete is harmful, and especially so where reinforcement is used, as it weakens the concrete and causes excessive corrosion of the reinforcement. Calcium chloride, however, may be used up to 3 per cent by weight of the mixing water or about 1 5 pounds per sack of cement, without harm to the concrete, and when used in that amount will lower the freezing point about 20 degrees.

Manure should never be used to cover newly laid concrete, as the acids contained in the manure are harmful. Hay and straw, properly weighted down, will often protect concrete against temperatures slightly below the freezing point. The safest policy, however, is to keep the temperature of the pavement at 60 degrees or above by artificial heat for five days after laying, when it may be exposed to very low temperatures without harm being done.

It would be manifestly impossible to describe all of the plant layouts that are being used in the construction of concrete pavements or to recommend any one as being the best for all conditions.

The conditions existing on each job must control the kind of plant best suited for the job and also the plant layout. The tendency, however, is towards the adoption of central proportioning and central mixing plants with the proportioned ingredients or the mixed concrete transported to the job, either on industrial railroads or by specially made motor trucks.

The use of industrial tracks laid on one shoulder of the road has the advantage of preventing cutting up of the subgrade after it has been prepared for the concrete. This is particularly true where the soil is of a sandy nature and also during wet weather on clay soils. The practice of depositing the materials on the sub-grade ahead of the mixer should be avoided whenever it is possible to do so.

When it is realized the saving in concrete that may be affected by having an even true sub-grade, properly rolled and uniformly compacted, and also how much more uniform in thickness the slab will be, the advantages due to keeping the materials off of the sub-grade will be appreciated. In one state the limits of sub-grade finishing are one-fourth inch low and one-eighth inch high, and while this may seem to be an excessive requirement, it is believed that a much closer adherence to section and grade than is common in many places should be insisted upon.

Care and good judgment must be used in equipping a job to see that the outfit is properly balanced in such a manner that there is no idle equipment and that one part of the job does not hold up the remainder. This can, of course, only be done by careful study of the conditions on each job and equipping accordingly. There is as much danger of over equipping as there is of under equipping it and then the job must be charged with costs that should not rightfully be there.

With regard to the use of central mixing plants, it may be said that concrete may be hauled with proper equipment up to the economical limit without harm to the concrete itself. The old idea that we cannot break what has been known as the initial set has been exploded and concrete has been hauled up to four or five miles with a lapsed time of over forty minutes without harmful effects.

Having decided upon the general features of design of a highway or pavement, we come to what is in reality the most important feature of all, the design of the mixture to be used in making the concrete itself.

The old saying that "you can't make a silk purse out of a sow's ear" was never so applicable as it is to a concrete road surface. You can never build a good concrete highway or pavement out of a poorly designed concrete mixture. There have been concrete surfaces that have failed and there will be others built that will fail just so long as the proper principles of design of the mixture are ignored.

Only too long have we taken the four ingredients that make up concrete and placed them together according to an empirical formula that may have given fair results with a certain lot of ingredients, but will give an entirely different result with a different set.

We have said to our contractors, "You mix up any ingredients you can get, that have certain physical qualities, in certain proportions, and we will take the responsibility for the result obtained." We have not known what results would be obtained, but because a certain proportion gave satisfactory results (probably at that not the best results obtainable), we have gambled that the same proportions would give as satisfactory results everywhere. Isn't it about time that we looked upon concrete as being what it really is, a scientific mixture that should and can give certain desired results with the particular ingredients available.

There is no other construction material that is accepted without testing the finished product, and there is all the more reason that concrete should be judged by tests of the finished product, since it is a material made on the job.

Steel, brick, tile, pipe and many other materials are made in a mill or plant and are all tested before shipping to be sure that they meet the requirement of the contract, but because concrete is made "on the job" these tests of the finished product have not been deemed necessary and yet this very fact should make it all the more desirable that such tests should be made.

With the understanding of the fundamentals entering into the making of concrete, we are able today to forecast the strength of the finished product very closely and there is absolutely no reason why contracts should not be based upon the delivery of a finished product that will meet certain desired requirements.

Good concrete is not merely "a mixture of sand, gravel, pebbles or stone chippings with cement" as one dictionary tells us, but is a mixture of cement, water and aggregate so proportioned, mixed, placed and protected during hardening as to develop all of the strength and ability to resist abrasion that are inherent in the ingredients.

When considering methods of making good concrete, it should be realized that none of the processes used can of itself bring about any of the qualities desired in concrete into the ingredients, for each combination of ingredients contains in itself certain concrete making qualities and the bringing out of these qualities is entirely dependent upon the processes to which they are subjected.

WATER-CEMENT RATIO.

Among the many facts established at the Structural Materials Research Laboratory at Lewis Institute, Chicago, the most important and far reaching in effect is the "water-cement ratio" theory. It has been demonstrated, without the shadow of a doubt, that the ratio of the volume of the water used in mixing to the volume of the cement in a batch, controls the strength of the concrete to a far greater extent than any other factor entering into its making.

So long as we keep the mixture plastic and all other factors the same, the lower the water-cement ratio the stronger will be the concrete. This one factor has so great an effect that cutting the ratio from 1.00 (one cubic or 7.5 U. S. gallons to one sack of cement) to 0.75 or 5.6 gallons to the sack, will increase the compressive strength 50 per cent.

This factor also has approximately the same effect upon the wearing qualities or the ability of the concrete to withstand abrasion. This property of concrete has always been attributed primarily to the hardness of the aggregate, but it has been proved that compressive strength and resistance to abrasion go very nearly hand in hand and are both to a surprisingly large extent independent of the hardness of the aggregate.

With a direct relation established between the water ratio and the compressive strength of concrete and simple but efficient means devised for controlling this factor, it becomes possible to forecast the strength of the concrete provided the rules laid down are carefully followed. Herein lies the practical value of the facts brought out by these investigations. The ability to forecast the strength of concrete places the material on a scientific basis and effects considerable economy, since it insures the development of all the latent qualities in the ingredients.

FINENESS—MODULUS.

The investigations also disclosed a factor called the "fineness modulus" which bears a very intimate relation to the water ratio and plasticity of the concrete. This factor, which is a simple function of the sieve analysis of the aggregate, furnishes us with an index of the amount of water required for producing a desired plasticity and through this factor a certain desired strength in the concrete.

The fineness modulus also reflects the strength making qualities of different sizes and gradings of the aggregate. Due to the fact that sizes and gradings of the aggregate which have the same "fineness modulus," possess the same strength making qualities, other factors being the same, we are able to design concrete mixtures of the same strength from many different gradings. The great saving and economy that can be effected by this knowledge will be realized by those who have been confronted with the problem of utilizing local aggregates with unsatisfactory gradings according to present ideas, as against the importation of much more expensive materials.

The fineness modulus is not the only measure of the grading that can be used in the design of mixtures, but other measures, such as surface area, surface modulus, etc., may be used if their value is thoroughly understood and properly applied. It is believed, however, that the fineness modulus is the most reliable and simple of all measures and when intelligently used will produce the most reliable results.

It would seem unnecessary to be obliged to urge the advisability of judging concrete by its qualities as a finished product, but so accustomed have engineers and constructors become to working by empirical formulas without regard to the results produced, that considerable urging is needed. By indicating methods for solving some of the problems involved, it is hoped that the practice of working for a certain desired finished product will become more prevalent.

Before taking up methods of designing a mixture let me call attention to an example of the use of these principles.

The Nevada Highway Commission was confronted with the question of using a local material containing an excess of sizes between one-fourth inch and one-half inch, which involved a considerable waste and expense to eliminate by screening. By proper laboratory investigation and the application of the fineness modulus and water-cement ratio theory, a mixture was designed that permitted the use of the aggregate without waste. Recent tests of concrete as actually placed in the roads show an average compressive strength of 3,200 pounds per square inch as against 2,100 pounds obtained with the screened material. Not only was a considerable expense saved, but the concrete was increased in strength over 50 per cent.

The average concrete obtained by ordinary methods probably does not attain a strength of over 2,000 pounds per square inch and the general run is nearer 1,600 to 1,800 pounds. If these mixtures had been scientifically figured, the same strength could have been attained with a much smaller amount of cement, or an increased strength could have been secured with the same amount of cement and a smaller yardage used in order to carry the same loads.

DESIGNING MIXTURES OF KNOWN STRENGTH.

The solution of a very common problem—how to obtain a concrete that shall have a certain compressive strength, with known sand and pebbles or broken stone—is a very simple matter and can be made at a very small cost with the minimum amount of equipment and without a laboratory.

Abrams' Tables of Proportions and Quantities used in solving this and other problems have been very carefully prepared. These tables were prepared by Prof. Duff A. Abrams at the Structural Materials Research Laboratory, based on experimental studies of concrete carried out through the co-operation of the Portland Cement Association and Lewis Institute. The investigations on which these values are based covered a period of about seven years and included nearly one hundred thousand tests.

Separate tables of Proportions and Quantities of Materials have been prepared for concrete of strengths of 1,500, 2,000, 2,500, 3,000, 3,500 and 4,000 lbs. per square inch at the age of 28 days, using fine and course aggregate of different sizes and a wide range of consistencies as measured by the slump test. The proportions are based on the compressive strengths of 6 by 12-inch cylinders, made and stored in accordance with the Tentative Methods of Making Compression Tests of Concrete of the American Society for Testing Materials. The principal features of this method are: Aggregates dry and of known sieve analysis, proportion by volume, concrete hand-mixed; puddled in metal cylinder forms, generally 6 by 12 inches in size. Plasticity of concrete controlled by slump test, specimens cured in damp sand and tested in compression at 7 and 28 days.

The quantities of materials per cubic yard of finished concrete given in the table are NET quantities, *no allowance* being made for waste. The conditions peculiar to each job should govern waste allowances which the estimator should base on experience or other data available; for average conditions, the following allowances for waste are suggested:

Cement 2 per cent, fine aggregate 10 per cent, coarse aggregate 5 per cent.

The above percentages do not include any allowance for grouting, patching, washing or replacements.

The purpose of the tables is threefold:

(1) To furnish a guide in the selection of mixtures to be used in preliminary investigations of the strength of concrete from given materials.

(2) To indicate proportions which may be expected to produce concrete of a given strength under average conditions where control tests are not made.

(3) To furnish a correct basis for comparing the relative economies of concretes made from aggregates of different sizes when the plasticity and strength of the resulting concrete are taken into account.

The value of the tables of Quantities of Materials is not in their use for estimating, but in comparative studies of different aggregates and combinations. The quantities are based on laboratory investigations, with aggregates measured dry and carefully rodded or puddled. Allowance must be made when using the tables for estimating, for the different results obtained when aggregates are measured in the loose condition common to field measurements. There will be but little difference, if any, in the measurement of broken stone or pebbles due to the two methods, but the measurement of sand will show a difference of from 5 to 20 per cent according to the moisture content.

If the proportions to be used in the work are selected from the table without preliminary tests of the materials and control tests are not made during the progress of the work, the mixtures in bold-face type should be used.

The use of these tables as a guide in the selection of concrete mixtures and for comparing different mixtures is based on the following:

(1) Concrete must be plastic;
(2) Aggregates must be clean and structurally sound;
(3) Aggregates must be graded between the sizes indicated;
(4) Cement must meet the requirements of the Standard Specifications and Tests for Portland Cement of the American Society for Testing Materials.

The plasticity of the concrete shall be determined by the slump test carried out in accordance with the following Tentative Specifications for Workability of Concrete for Concrete Pavements of the American Society for Testing Materials.

"In determining workability, the newly mixed concrete shall be placed in a truncated *cone-shaped metal mold* 12 inches high, 8 inches in diameter at the base, and 4 inches in diameter at the top, and provided with handles at the sides. The concrete shall be lightly tamped with a rod as it is placed in the mold which, when filled, shall be immediately removed and the slump or settlement of the concrete noted."

The equipment required for the solution of this problem consists of a set of standard square mesh sieves in the U. S. Standard Series having the following sizes: Numbers 100, 50, 30, 16, 8, 4, ⅜, ¾, 1, 1½ and 3 inches, also some accurate means of weighing the samples of aggregate, and a sheet metal form in the shape of a frustrum of a cone 4 inches in diameter at the top, 8 inches at the bottom and 12 inches in height, with a bail or handles on the sides.

In taking samples of the sand and stone for sieve analysis great care should be used to insure that the sample is one that represents the grading of the whole body. Always remember that there is a tendency where stone and coarse sand are stored in piles, for the larger particles to roll to the bottom. A sample weighing from 1½ to 2 pounds of sand and one weighing 10 pounds of stone should be secured for making the analysis. In order to obtain this, the original sample should consist of about 50 pounds of fine and 100 pounds of coarse aggregate and the final sample should be obtained by quartering or by use of a sample splitter. By doing this the final sample will be representative of the grading of the supply.

SAMPLES OF AGGREGATES.

The samples should be thoroughly dried before making the sieve analysis in order to obtain correct results. Do not use too great a heat in drying out the samples (not over 250° F.) as some aggregates will break down under excessive heats and consequently a false grading will be obtained.

Having prepared the samples of fine and coarse aggregate in the manner outlined, separate each sample with the standard sieves. Note the largest size sieve upon which is retained 15 per cent or over (by weight) of the total of each sample, also the smallest size sieve through which 15 per cent or less (by weight) of the coarse aggregate will pass. This will classify the aggregates as follows: The sand will be called 0 to the number of sieve next larger than the largest size retaining 15 per cent of the sand sample; the coarse aggregate will be classified as falling between the smallest size sieve noted for the stone and the number next larger than the largest size noted.

EXAMPLE.

Assume, for an example, that we find by this method the sand is classified as 0 to 4 and the stone as 4 to 1½ and that we want a 3,000 pounds compressive strength concrete. We would then look in "Abrams' Tables of Proportions and Quantities" and obtain the correct proportion for the mixture with a plasticity suitable for the work at hand. The tables give the correct proportion with each combination of fine and coarse aggregate for slumps ranging from one-half to ten inches, or from quite stiff to very plastic concrete.

PLASTICITY AND WATER-CEMENT RATIO.

Remember always that the strength of the concrete depends upon the water-cement ratio, consequently the water-cement ratio will be the same for every proportion shown in a table for a given strength. *This can mean only one thing, namely, if we need a high plasticity because of the nature of the work, we must add more water than that required for a low plasticity and at the same time add sufficient cement to maintain the same water-cement ratio in order to obtain the same strength.* Because of this, a concrete that will give an eight-inch slump will require much more cement than one that will only give a one-inch slump, consequently economy demands as low a slump or as dry a consistency as the nature of the work will permit. *Increased plasticity or flowability for the same strength can only be bought with one coin, cement: it cannot be bought with water, aggregate or any other material.*

The water-cement ratio is the ratio of the volume of the water used in mixing to the volume of cement in a batch. A water-cement ratio of 1.00 equals 1 cubic foot or 7.5 U. S. gallons of water to 1 sack or 94 pounds of cement. The ratio is sometimes computed by using weights, but it is believed that the use of volumes will be found more convenient.

To continue with our example, we find the mixture called for in the table will be 1:1·7:3·4, if we are to use a concrete having a slump of one-half to one inch and will require 1·45 barrels of cement per cubic yard of finished concrete. If we desire a concrete having a slump of eight to ten inches with the *same strength* we must use a 1:0·5:1·4 mix which will require three barrels of cement per cubic yard, or more than twice that required for the stiffer consistency. This illustrates the saving effected by using the stiffest consistency possible.

Having determined from the tables the mix required for the planned plasticity or slump, the correct amount of water may be determined that will give this degree of plasticity and the water-cement ratio computed. In order to do this, concrete of the indicated proportions should be made and the volume of water measured that will produce the correct slump. From this the number of gallons of water to be used for each batch can be computed. This amount depends, of course, on the size of the mixer and is usually a multiple of the amount required for one sack of cement.

It is not necessary, as a general rule, to figure the water-cement ratio, as this can be controlled entirely by the slump of the concrete but it is suggested as a means of familiarizing one's self with this factor and as a check against excessive changes in field operations.

Undoubtedly there will occur many cases where it will be found that a much stiffer consistency can be used on the work than that considered in designing the mixture, especially until engineers and constructors become familiar with the various slumps of concrete. When this occurs, it will be well worth while, due to the saving in cement, to change the proportions to agree with the slump established as being correct.

If the correct water-cement ratio has been determined, steps must be taken to insure maintaining this ratio throughout the entire work. Allowance must be made for the moisture content of the aggregate due to rain, being wetted down, etc. It can be readily seen that if the water measuring device on the mixer has been set to deliver the proper quantity of water to give the required slump with the aggregates dry, less water will be required when the aggregates are wet, consequently a new slump test must be made and the measuring device reset.

ECONOMY EFFECTED.

As an illustration of the economy that design of concrete mixtures by this method will effect, consider the following example: With sand 0 to 4 and stone 4 to 1½, cement at $3.50 per barrel, sand at $1.50 per cubic yard and stone at $2.50 per cubic yard. Suppose we use a 1:2:4 mixture, following the common practice of proportioning. Numerous tests have shown that concrete of this mix as usually produced will have an average strength of about 1,500 pounds per square inch at 28 days, and a much lower strength when mixed to give a slump of 9 to 10 inches as is only too frequently done.

Quantity tables in common use give the quantities per cubic yard for this mix as 1·51 barrels cement, 0·45 cubic yards sand and 0·89 cubic yards stone, but in order to have a proper basis for comparison, we will use quantities figured on the same basis as those in Abrams' tables with a proper allowance for waste added. We then find the quantities for a 1:2:4 mix to be 1·28 barrels cement, 0·41 cubic yards sand and 0·80 cubic yards stone, costing $7.10.

On looking in Abrams' tables we find that, by using the proper water-cement ratio we can obtain the same strength, 1,500 pounds, with a 1:3·5:5·4 mix and the quantities with same waste allowance are 0·89 barrels cement, 0·50 cubic yards sand and 0·74 cubic yards stone, costing $5.72. Thus a saving of $1.38 per cubic yard is effected.

Looking at it another way we find that, by using the proper mix and water ratio from Abrams' tables we can produce a 2,500 pound concrete at approximately the same cost for materials. Therefore we can increase the strength by two-thirds without additional cost.

SPECIFICATIONS.

There remains one phase of the problem, however, to which careful study and thought must be given. How shall the specifications and contracts be drawn in order that proper control of the construction may be had and the desired results insured? It is manifestly impossible to lay down fixed rules that would cover all conditions under which contracts are let, and the clauses suggested are only intended to cover fundamentals. It may be necessary to omit certain of these clauses, or add them as the conditions peculiar to each contract demand.

1. Compressive strength.

(a) It is the intent of these specifications that the concrete in place shall have a compressive strength at 28 days of....................pounds per square inch.

(b) The test specimens shall be moulded and handled in accordance with "Tentative Methods for Making and Storing Specimens of Concrete in the Field" (C-31-20T American Society for Testing Materials).

(Note—Samples of the concrete are taken immediately *after* it is placed. The test pieces are generally 6″ x 12″ cylinders for smaller sized aggregates and 8″ x 11″ for aggregates over 2″. The concrete is puddled when placed in the mould, specimens are stored in damp sand and tested at 28 days.)

(c) The number and frequency of specimens to be taken shall be fixed by the engineer, but shall be in all cases sufficient to furnish an index of the strength of all parts of the structure, allowing two or more specimens for each section.

(d) When the strength of the concrete placed in a section or structure falls more than 15 per cent below the contract strength (as indicated by the tested specimens), that section or structure shall be replaced by the contractor, without expense to the owners.

(e) Whenever possible, seven day tests of the concrete specimens shall be made, and, when the strength of these tests falls below 50 per cent of contract strength at 28 days, steps shall be taken at once to improve the quality of the concrete to be placed.

2. Consistency.

(a) The water-cement ratio determined upon for any particular strength shall be maintained throughout the work.

(b) The water shall be measured by an automatic device that will insure the same quantity in successive batches. The mixer shall be equipped with a water-measuring device controlled from a case which can be kept locked and so constructed that the water can be discharged only while the mixer is being charged.

(c) In order to maintain the correct water-cement ratio, the amount of water to be used per batch shall be controlled by making a slump test in the prescribed manner, at least once in every four (4) hours when placing concrete. A slump test shall also be made whenever the size and grading of either or both of the aggregates shall change, or their moisture conditions shall change and at such other times as may be deemed advisable.

3. Proportions.

(a) The contractor shall indicate, when submitting his bid, the source and grading of the aggregates, proportion of cement and aggregates and the slump he intends to use. The proportion shall be obtained by use of "Abrams' Tables of Proportions and Quantities" in the manner prescribed herein.

4. Compensation.

(a) The proportions indicated in the bid shall be used in determining the unit compensation for the various classes of concrete and the contractor shall be paid for additional unit quantities of material made necessary by any change in these proportions during the progress of the work, on written instructions from the engineer, upon submitting sworn claim supported by material bills.

(b) When changes in proportions are made subsequent to the letting of the contract that effect a reduction in the unit cost of materials required, this saving shall be deducted from the compensation due the contractor.

(c) Upon demand of the engineer, in the event of changes in proportions, the contractor shall furnish him with sworn material bills as a basis for adjusting the compensation.

(d) The quantities shown in Abrams' tables are exact quantities per cubic yard and any additions thereto for wastage shall not be considered in claims for additional compensation.

These suggested clauses have been drawn with three objects in mind.

1. To specify a result rather than a formula.
2. To specify in such a manner that contractors can make an exact bid.
3. To provide a reciprocal contract that will protect both owner and contractor.

Improper Use of Principles.

It is believed advisable to include a warning regarding the harmful effects of improper use of the principles outlined, and against the use of them in part without following through to the end. No theory or principle can be used in part without great danger of doing more harm than good. Cases have come to notice where the low cement contents shown in "Abrams' Tables of Proportions" have been put forward as a justification for reducing the amount of cement used with an empirical mixture. Nothing else was done, the water was not cut down nor were the aggregate reproportioned and as a consequence much weaker concrete was the result. Such misuses of the principle involved in the water-ratio theory do a great deal of harm and unless *all* the rules are followed, no part of them should be used.

The rules are not severe, nor are they hard to understand with a little study, and the economy and increased strength that may be had by the use of them, is well worth many times the trouble of abandoning present ideas and adopting new ones.

Fundamentals Other Than Design.

So far, attention has been directed to only one phase of concrete making, the design of the mixture. It must be remembered that this is not all there is to the making of good concrete but is only one part, albeit an essential part, in the making of this product.

The fundamentals that must be observed for the best results have been described many times, but a brief outline of some of them will not be out of place here. Sands should be clean, hard, free from clay or silt except in small percentages and they should be tested by the "Colorimetric Test for Organic Impurities." Coarse aggregates must be durable, clean, free from organic matter and dust. Bank run or crusher run aggregates must not be used.

All concrete must be turned in the mixer at least sixty (60) seconds after all the ingredients, including the water, have been placed in the mixer drum. After the concrete is in place it must be kept from drying, by covering with water (Ponding) or wet earth or by sprinkling. The concrete should be kept wet in this manner for twenty-one (21) days. These rules are all essential for the making of good concrete and must be followed whether the concrete is proportioned by the water-cement ratio theory or by any method whatsoever.

In closing let me say a word regarding inspection, for after all it is upon the inspection of the work that the success or failure of a road depends. No matter with what care laboratory investigations are made, mixtures are designed, and rules for construction details are laid down, it is upon the knowledge of fundamentals and the enforcement of these rules by the engineers in charge and the inspectors that the results, be they good or bad, are obtained.

These men must constantly read and study in order thoroughly to understand all the fundamental principles involved and must stand ready to make instantaneous decisions and make them rightly in order to obtain the best results with the least delay. Materials must be constantly watched, analyzed, and tested, and each individual batch of concrete must be watched to see that it has the proper proportions of the ingredients and that they are properly mixed and placed. Each batch makes up a number of square yards of pavement and several poorly made batches in a day's work mean many weak spots in a mile.

When some or many of these weak spots fail as time goes on, attention is drawn to them and away from the much larger area of good pavement and the whole work suffers because of them.

Because of these things the price of perfect work lies in the employment of proper principles in design, in an understanding of these principles by all connecetd with the work, and in exercising "eternal vigilance" to see that the rules are properly enforced.

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BOOKS

By T. A. Rickard

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Before books came writing, and before writing came language. Primitive man, like a child, started to write by means of rudimentary pictures, from which was developed sign-writing, such as the cuneiform or wedge-shaped marks of the Assyrians, the pictographs or picture-writing of the Chinese, and the hieroglyphics or priestly script of the Egyptians. From the signs for words were developed the signs for syllables, just as each act in a charade represents a syllable. From syllables was developed a system of sound-signs—an alphabet. Thus writing grew from the pictorial record. Paleolithic man began by scratching pictures of reindeer and musk-oxen on the walls of his cave. His descendants cut their drawings and scribbled their runes, or mystic marks, on pieces of bark; then on clay; and at last on various kinds of parchment and paper. As an illustration of rudimentary writing by means of signs I may repeat the story of a rustic shop or store, the owner of which kept his accounts by means of picture-writing, and on one occasion inadvertently charged his customer, the local miller, with a cheese instead of a grindstone, because he omitted to mark the hole in the centre.

By aid of written records man was enabled to transmit his traditions; thereupon he established his domination over the other primates. For a long time he could only multiply his writings by copying them; his books therefore were few and costly; but with the invention of printing he was enabled to multiply his books, to make them so numerous and so cheap that they served not only a privileged few but any of his fellows who had a mind to read, and by aid of books he gave the record of his experience and of his knowledge to all mankind. With books was born what is called civilization, which is the art of living in a community in a rational fashion.

A 'book' is a literary production of some bulk, usually bound. 'Book', 'bible', 'parchment', 'paper', 'library', 'volume' —in these six words is told the romantic history of the art of book-making. 'Book' is derived from the Anglo-Saxon *boc*, meaning 'birch', for strips of birch-bark were used for cutting or inscribing runes in the days before parchment or paper was known. 'Bible' comes from the Greek *biblos*, meaning a 'book', but originally used to designate the papyrus on which the ancient writings were recorded. 'Paper' is a derivative from *papyrus* through the French *papier*. 'Parchment' comes through *pergamentum*, the name given to the skin of sheep and calves prepared for writing purposes, and *pergamentum* in turn preserves the name of the originator of this practice, a king of Pergamum, who flourished in the second century B. C. The word 'library' is derived from the Latin *liber*, a book, but originally it referred to the inner bark of a tree and was applied to the papyrus tissue, which had a bark-like appearance. 'Folio' comes from *folium*, a leaf. 'Volume' is the Latin *volumen*, a roll, on which the strips of papyrus were wound. Thus the derivations of these words open the windows of the imagination to the perspective of history and suggest the devious ways by which the modern book has reached its present form.

The earliest books were the clay tablets on which, 2400 years B.C., the people of Babylon recorded their legal decisions, revenue accounts, contracts, and loans. The inscription was made in cuneiform or wedge-shaped characters on clay by means of a *stylus*, a sharp-pointed instrument of metal, wood, or ivory. From *stylus* is derived our word 'style'. Some of the Assyrian writing was so small and so skillfully executed as to suggest that a magnifying glass was used—probably a ball of crytal. The clay of these Babylonian tablets was hardened after they were inscribed; then they were placed in jars, arranged on shelves, and labeled by means of other tablets attached to them by means of straws. To protect the writing it was customary to enclose the tablet inside a second cover also made of clay. In the reign of Sargon II, in the 7th century, B.C., there existed at Nineveh a library consisting of a collection of such tablets, the narrative being continued from one tablet to another, and some of the tablets were inscribed with entries to serve as a catalogue. Macaulay refers facetiously to a rising Assyrian architect "who published a bridge and four walls in honor of the reigning emperor."

These tablets can hardly be considered the direct ancestors of our modern books; more properly our books may be deemed the descendants of the papyrus manuscripts. The most ancient of them is a roll of 18 columns of Egyptian hieratic (or priestly) writing of about the 25th century B.C., and therefore nearly contemporary with the oldest Babylonian tablet. This Egyptian document records the maxims of Ptah-Hetep. The papyrus was made from the pith of a reed, the pith being ground into a pulp; then it was cut into strips, which were laid side by side, and a second layer of strips was superimposed at right angles. The two layers thus woven were soaked in the glutinous water of the Nile, hammered, and dried in the sun. Any rough spots were flattened by polishing with a smooth shell or a piece of ivory. The use of papyrus for writing material is believed to go as far back as 4000 B.C., and it continued in vogue until the Christian era; indeed it served for pontifical bulls as late as 1022 A.D., and occasionally even later. When papyrus was used, the form of a book was a roll, or volume; the narrow bands of papyrus being wound upon a stick or a series of sticks. From this ancient custom we inherit the practice of setting type in columns. Here I may explain that the ancient writing, on papyrus or vellum (another name for parchment; 'vellum' is derived from *vitulus*, a calf, and is closely related to 'veal'), was arranged in one of three ways: (1) in short lines at right angles to the length of the roll, (2) in long lines running the entire length of the roll, or (3) in short lines parallel with the length of the roll but arranged in columns, each of which had a space on both sides.

Papyrus unfortunately was sensitive to damp, and therefore deteriorated readily so as to crumble away in course of time. It is fair to say that some of our modern paper is no more durable, but our libraries afford better protection. The decay of papyrus was the cause of the disappearance of much of the classical literature and led to the adoption of fine dressed skins as a writing material. The introduction of skins, of calves and sheep, by Eumenes, a king of Pergamum, in the second century B.C. was due to the fact that he found it difficult to procure a supply of papyrus from Egypt, because the Ptolemies were jealous of the library that he was establishing in opposition to that of Alexandria. On parchment the writing could be rubbed off or rubbed in, so as to permit a fresh writing to be superimposed. The new text usually was written crosswise with the old, to prevent confusion, and sometimes the uncompleted erasure left the outline of the old characters in such a condition that they could be restored by the aid of chemicals. To these restorations, or palimpsests, we owe many literary treasures that had been hidden under later writings.

Parchment retained its supremacy until the 10th century, when a new writing material was introduced from the Orient. This was made from a pulp of linen rags, and to it was given the name of the obsolete papyrus—'paper.' It came to Europe from China, where it was used as far back as the second century B. C. From China it came westward almost by accident. In 751 A. D. an attack of the Chinese on the Arabs of Samarkand, in Turkestan, ended in a repulse and the capture, among others, of several skilled paper-makers; these taught their trade to their captors, the Arabs, who in turn brought it still farther westward, the first paper mills in Europe being established by the Moors in Spain in the 12th century. Their paper was a cloth parchment. Good paper was made in Italy in the 13th century, and in Germany in the 14th. Thus the use of rag-paper came into favor; but it came slowly, until the invention of printing, in the early part of the 15th century, created a wide demand for a material that could be used on a press. Thereupon rag-paper enjoyed a monopoly until the 19th century, when cheap substitutes were made out of wood-pulp and esparto grass. Modern paper is a tissue of vegetal fibre. Rag-paper and parchment are used still for special purposes, and serve as links with the storied past.

The ancients used various materials for their writing. Hannibal engraved a history of his campaigns on bronze plates. The Romans ordinarily used *tabulae,* tablets of wood covered with wax, on which the writing was recorded by means of the stylus, which is the ancestor of our pen. These tablets, usually in pairs, or diptychs (meaning folded), were protected from contact by a raised margin or by opposite projections in the centre. At Pompeii a number of these diptychs were found, one of them being the record of a payment made in the year 55 A. D. This is the earliest known Latin manuscript. The Pompeian diptychs consisted of wooden leaves, hollowed on the inner side and filled with a black wax on which the writing was scratched. They were hinged together with leather thongs.

The earliest use of a protective cover for books comes to us from Assyria, where in the 8th century B. C. the clay tablets were enclosed in an outer clay shell, on which a short title was impressed. The Egyptian rolls of papyrus were bound with papyrus tape, and sealed with Nile mud, the rolls in turn being preserved in rectangular hollows cut in wood. The first binding of books took the form of wooden boards covered with stamped leather, half of the board sometimes being left uncovered, so that the earliest printed books were extremely large and heavy, partly because of this crude binding, but also on account of the thickness and strength of the paper itself. Not until the 19th century were glazed calico and cloth introduced into book-binding, thereby making books less cumbersome.

The art of printing is based upon the use of stamps and dies, such as the ancients had for producing seals and coins. The goldsmiths of the Middle Ages were skillful in modeling, engraving, and casting. It is surprising therefore that typography should have been so slow in making its appearance in Europe. This suggests, as H. G. Wells has said, a gap in the social system between men of thought and men of technical skill. One reason for the belated appearance of printing was the delay in the introduction of paper.

Printing, both from blocks and from movable types, was practiced by the Chinese and Japanese long before it was known to the Western world. In 175 A. D., it is said, the text of the Chinese classics was cut upon tablets, from which impressions were taken. The use of wooden blocks for printing can be traced as far back as the 6th century, when the founder of the Suy dynasty had the remains of the classical books engraved on wood; but it was not until the 10th century that printed books became common in China. The use of movable types of clay was known to the Chinese in the 11th century, and to the Koreans is credited the invention of copper types at the beginning of the 15th century.

In Europe the impressing of figures, letters, and words on parchment was done long before printing of the modern kind was started. Medieval princes, such as William the Conqueror, had their monograms cut on blocks of wood or metal, and used them in signing their charters. Manuscripts of the 12th century exhibit initials so uniform as to warrant the belief that they were made by means of stamps or dies. Nevertheless, until the 14th century all books and documents were written by hand, the figures and pictures being drawn with the pen or painted with the brush. This method of writing, transcribing, and illustrating by hand had reached its highest development when the art of printing, from wooden blocks on silk, cloth, vellum, and paper, made its appearance suddenly. The inventor was Laurence Koster, of Haarlem, in Holland. The date was 1441. Soon afterward John Gutenberg started to print at Mainz, in Germany. When the art had been well developed at Mainz, the siege and capture of that city in 1462 caused a dispersion of the printers and led to the introduction of printing into the lands to which they fled—Italy, France, and Spain. The man who introduced printing into England was William Caxton, who was sent by Edward IV to negotiate a treaty with Philip of Burgundy, and while abroad learned the mysteries of printing and issued his first book, 'The Romantic History of Troy', at Cologne in 1465. This was the first book printed in the English language, but the first book to be printed in England was 'The Game and Play of Chess', which Caxton issued from his press at Westminster in 1474.

In the first blocks the lines to be printed were cut in relief. The text, engraved upon the wood, was wetted with a liquid resembling distemper, and then a sheet of damp paper was laid upon it, after which the paper was rubbed with a burnisher until the impression was transferred from the ridges of the carved block to the paper itself. Between the time of block-printing and the introduction of cast-metal types there was a short period during which the early printers used movable wooden types, perforated and joined to each other by a thread. Until cast-metal types came into general use, the printing of books was done not by 'quires' or 'quaternions'—that is, groups of four sheets—but page by page. The metallic type was made by means of a punch, a matrix, and a mold. The first punches, like the book-binder's stamp, were made of brass. The punch, or *patrix*, was pierced into the cold lead, producing the matrix, from which the letter was made by hammering the matrix into the metal, which was heated sufficiently to be soft. Thus each printer had to learn how to engrave and cast the type he used. The early printing imitated handwriting, so that the appearance of books changed but little at first. Printing that simulates handwriting survives in the *italics*, or Italian type, which is used for emphasis and other special purposes. It is said to be an imitation of the handwriting of Petrarch.

In making type today the letter is cut on the end of a piece of steel. This, the punch, is then hardened. When the letter is perfected it is driven into a piece of polished copper, which becomes the matrix, wherein the face of the type is formed under pressure. In the very latest practice the matrix is engraved in a machine, to any size required; of this machine I need only say that a needle-point is clumsy compared with the instrument that makes the fine lines on which the type is cast. The setting of type by hand still lingers, especially in display printing, as of advertisements, and for fine work, but for the printing of books and newspapers this slow method has been superseded by machines, such as the linotype, which casts the type in lines, and the monotype, which casts individual letters. Modern type is made of an alloy of lead and antimony, the latter having the quality of expanding on cooling, and so causing the alloy to fill the matrix exactly. Antimony also hardens the lead; for which purpose likewise a little tin is added. In linotype metal the proportions are lead 79%, antimony 16%, and tin 5%.

The linotype makes a line of type, called a 'slug'; these slugs fall in proper sequence into a tray, from which they are removed into another metal tray, called the 'galley'. From this the slugs or lines are removed, and arranged according to the size of page required, in a steel frame, called the 'chase'. A group—four, eight, or sixteen—of such pages in a frame constitutes a 'type-form'.

The cheapening of printing on a large scale is due mainly to the introduction of electrotyping for books and of stereotyping for newspapers. By such methods the quantity of type needed is diminished, the wear of the type is decreased, and duplicates of the type-forms aré made for the purpose of expediting the printing. In the electrotyping process the type-form, or aggregate of pages in type, is covered with a sheet of black wax, which under pressure takes the impression of the type. This wax negative is trimmed and then put into an electrolytic bath, where copper is precipitated on it, forming a sheet, or 'shell', on which tinfoil is brazed, or soldered, making a tin-plate, on which then the molten lead-antimony alloy, or type metal, is poured. Thus as many reproductions can be made as may be required. In the stereotyping process a matrix of *papier mâché* is made by pressure on the type-form; this paper matrix is then placed in a machine into which the molten metal is cast to the exact height required for type, namely, 0.918 inch.

With the introduction of printing, the gates of human knowledge were opened wide. On Koster's house at Haarlem was an inscription in which printing is described, as "Ars artium conservatrix", the art preservative of all arts. The copying of manuscripts had been a priestly craft and written records had been stored in monasteries; reading was the privilege of the few; with printing the art of book-making passed into the hands of students and artisans; it ceased to be a priestly prerogative. Knowledge no longer trickled in a tiny stream within narrow channels, it began to flow in a generous flood over the whole world.

Even before books became numerous they were stored in special buildings—temples, museums, and libraries. The collecting of books used to be a kingly sport because only royal munificence could meet the cost of many books, but in our day the multiplying of the productions of the mind has become relatively inexpensive, partly because the general spread of education has created a taste for books that has led to a wide and constant demand for them, and partly because the introduction of electrotyping has lessened the cost of producing them.

The first national library, which was in Egypt, was under the protection of the divinities; it was a temple dedicated to religion and literature, at a time when both were under priestly control. That early library had engraven on its front the motto: "The medicine of the mind". The Assyrians, as we have seen, made collections of their clay tablets, and these may be regarded as the ancestors of our libraries. Sardanapalus had a great library at Nineveh. But Ptolemy's library at Alexandria, built in the fourth century B. C., was the real forerunner of our modern library. It was a combination of a library and a publishing business, for it housed a large staff of copyists who made duplicates of the papyrus writings. An extensive trade in these was maintained with wealthy scholars all over the known world. The successors of the first Ptolemy continued to support the library. It is recorded that one of the Ptolemies refused to supply the famishing Athenians with wheat until they presented him with the original manuscripts of Aeschylus, Sophocles, and Euripedes. This was profiteering in literature with a vengence!

The Romans seized the diverse collections of writings belonging to the kings and nations they conquered, regarding these writings as among the most precious of the spoils of victory. Many illustrious Romans won fame because of their libraries—among others, Crassus, Caesar, and Cicero. Just before his assassination Caesar announced his intention to open the great library of Lucullus to the public. In this library or museum, Cicero himself often passed his time in reading, when his friend Faustus was the librarian.

Various aphorisms express the value of books and of reading. Bacon said: "Reading maketh a full man, conference a ready man, and writing an exact man". Matthew Arnold warned us against the careless use of books: "Desultory reading is a mere anodyne; regular reading, well chosen, is restoring and edifying." Elsewhere he referred to the eternal youth of ideas and the refreshing effect of reading on the mind: "Certainly I feel no older, and that is one great benefit of going on reading and thinking. One's sense of a freshness and newness in things remains". That is true. Most of us have known the delight of taking down "one of the magicians of the shelf" and going forth into a far country on the wings of the imagination; forgetting the present, with its possible irritations and worries; to be introduced to those among whom high converse is held and to linger in places illumined with the light of an undying romance. But of all forms of mental refreshment, give me an autobiography. Leslie Stephen has said that "nobody ever wrote a dull autobiography", and I agree, unless it be the lucubrations of Henry Adams. I have made two unsuccessful attempts to read that book. "The autobiographer", says Leslie Stephen, "has *ex officio* two qualifications of supreme importance in all literary work. He is writing about a topic in which he is keenly interested, and about a topic upon which he is the highest authority." One of the most fascinating books ever written is Rousseau's 'Confessions', in which the author turns himself inside out for the inspection of posterity. Another autobiography marked by superlative audacity is Benvenuto Cellini's 'Memoirs', which exhibits a disregard for morality that is the antithesis of priggishness. Cellini thought it the duty of eminent persons to recount their experience of life for the benefit of mankind. Another frank and introspective, but thoroughly moral, story of a life is Herbert Spencer's autobiography, the reading of which is as refreshing as a glass of cool water on a hot afternoon. The greatest autobiography in our language is that of Benjamin Franklin, the true and fascinating story of a supremely useful life. Perhaps the 'life and letters' type of biography is even more attractive than the autobiography pure and simple, because in such a book we have the man's story as told in his letters together with the connecting narrative of his life as recorded by a sympathetic friend. Of such books I recommended Huxley's 'Life and Letters' by his son Leonard Huxley, and the 'Life and Letters of Walter H. Page' by Burton J. Hendrick.

A few days ago I was in the library of the University of California gathering notes for this address. As I looked around, the suggestion of a contrast with the Alexandrine library came to me forcibly. In Ptolemy's library a few elderly students slowly unwound the rolls of papyrus and read laboriously the clumsy writing of the manuscript. If the student copied it, as most of the visitors did, he had to dry his last writing by waving the papyrus in the air or sprinkling sand over it. Whenever he wanted to refer back to what he had written he had to repeat this performance, lest he blot the writing into confusion. He could work only by day because no adequate device for lighting his library was available. The library in which I was working was well lighted, comfortably heated, and skillfully ventilated; at the series of tables were sitting six hundred students, young men and women, each with his or her individual light. They had plenty of paper and they used fountain-pens. In another similar lofty and beautiful room 800 other students likewise were at work preparing their essays and other tasks for the morrow. Instead of studying in a bedroom, in the unquiet atmosphere of a boarding-house, or amid the distracting surroundings of a fraternity home, they were privileged to prepare their work under conditions most conducive to comfort of body and concentration of mind. And the use of the books, as well as of the conveniences is given to the student gratuitously by the State. No better exhibit could be made for American democracy than the picture of these magnificent library-halls at night, filled with the budding citizens of our commonwealth engaged in acquiring the knowledge garnered on the shelves, in taking medicine for the mind, in beholding the soul of the past, enjoying the company of the master spirits of humanity, and holding high converse with the mighty dead.

Libraries today are not the particular resort of book worms as formerly; this statement can be taken both literally and literarily. At one time the construction of buildings and the care of them was so defective that books by the thousand were destroyed by fire, damp, and worms—the bookworm, known to science as *Anobium pertinax.* How pertinacious these rodents of books can be is told by Blades, the famous printer, who records the fact that they ate nearly through a stout folio printed in 1477. They bored their way through the front 86 pages, while their friends were boring their way through the back as far as the 69th page. They failed to complete their penetration. Whatever the quality of modern books in the matter of readability they are less edible than the old ones, simply because the *Anobium pertinax* turns away in disgust from china clay, gypsum, barite, and other ingredients of modern paper.

One can have too much of a good thing. We are subject alternately to action and reaction. To those of us who love books there come times when we rebel against the dust of libraries and protest against the vanity of learning, when we turn from our best beloved authors "as from a friend who has outstayed his welcome". Then it is that we mutter the words of Ecclesiastes: "Of making many books there is no end; and much study is a weariness of the flesh". The boyish spirit in us asserts itself irresponsibly, the magicians of the shelf cease to charm, the nook in the library become a prison, and we sally forth into the sunlight, eager to enjoy again the purely physical life that was ours before the hand of learning was laid heavily upon our brows. Assuredly the geologist among us will discover sermons in stones, the engineer will find books in the running brooks, and both will uncover good in everything. For we are but the children of a larger growth, and before Man gave us books Nature made us men. Therefore to know our fellows is a study more grateful than the reading of many books. "The proper study of mankind is man."

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ENGINEERING FEATURES OF THE MOFFAT TUNNEL

AFTER DINNER TALK

By D. W. Brunton
Chairman of the Board of Consulting Engineers to the Moffat Tunnel Commission

(At a dinner given by the Colorado Scientific Society, to which the city members of the four great National Engineering Societies were invited. Metropole Hotel, Denver, Colo., October 6, 1923.)

The construction of railroads across the state of Colorado from east to west is extremely difficult, because, Colorado is not only the highest state of the Union, but the Rocky Mountains, which cross the state from north to south, are higher, wider and more continuous in Colorado than in any other portion of the United States.

There are more square miles of territory in Colorado above 10,000 feet altitude and more peaks above 14,000 feet than in all of the other states in the Union put together. In fact, there are so many peaks above 14,000 feet elevation that seventeen of them are still unnamed.

The Argonauts of '49, in their wild rush to the gold fields of California, crossed the continent with ox teams, and to find fresh pasturage for their animals they were continually seeking out new routes, consequently the Rocky Mountain range was thoroughly combed out for low passes.

Years ago when railroad construction began, two favorite emigrant lines to the far west were found to be most suitable for railroad construction, namely, the Union Pacific line through Wyoming and the Santa Fe line through New Mexico and Arizona. In other words, the two great transcontinental railway lines veered away and passed Colorado to the north and to the south. The highest point on the Union Pacific is at

Sherman Hill, Wyoming, where the railroad reaches an elevation of 8,013 feet. The Continental Divide, however, is at Creston, 172 miles further west, where the railroad crosses the ridge that separates the waters which flow into the Gulf of Mexico from those which flow into the Pacific, at an elevation of 7,107 feet; or, in other words, the Continental Divide is 906 feet lower than Sherman Hill.

The Santa Fe comes directly west from Kansas City, but when it strikes La Junta, Colorado, it sheers off to the south, crossing Raton Pass in New Mexico at an elevation of 7,608 feet, and the Continental Divide at Glorietta Pass at an elevation of 7,431 feet.

The Denver & Rio Grande Western runs across Colorado in its route from Denver to Salt Lake, but to accomplish this it has to zigzag about so much that to reach the western boundary of the state at the Utahline, a distance of 220 miles in an airline from Denver, its length is 484 miles; and to reach Tennessee Pass, where it crosses the Continental Divide at an elevation of 10,240 feet, 74 miles in an airline from Denver, trains have to travel 281 miles.

When the Moffat Tunnel is completed, the Denver & Rio Grande Western Railway, by building a 42-mile line on a water grade up the valley of the Colorado from Dotsero to Orestod on the Denver & Salt Lake Railway, would shorten their line 174 miles, eliminate Tennessee Pass and the canons of the Arkansas and the Eagle.

The necessity of a direct route across Colorado from east to west, thus giving a short line to Salt Lake City and the Pacific Coast, was early recognized, but it remained for the late David H. Moffat to put a feasible plan into execution. He was extremely fortunate in securing for his chief engineer Mr. H. A. Sumner, who, knowing that there were no reasonably low passes in the state and none in anything like a direct line between Denver and Salt Lake City, made a careful survey along both sides of the range, at an elevation of about 9,000 feet, to locate points that would be topographically accessible and at the same time give the shortest distance through the range at this elevation. This location was found near the base of James Peak.

Up to an elevation of 9,000 feet, climatic conditions in this state are usually excellent for railroad operation, but above that elevation the snow remains perfectly dry during the winter and drifts so freely that it is extremely difficult to keep railway tracks open.

The eastern portal of the Moffat Tunnel, on which construction has now commenced, is at a point on the South Fork of Boulder Creek, about four miles above Tolland and 37 miles in an airline from the Union Depot in Denver. The western end of the Tunnel is located on the right bank of the Frazer River, a short distance above Idlewild.

Both the South Fork of the Boulder and Frazer follow old glacial channels and afford wonderful examples of the erosive work of the immense ice sheet which, at no distant date geologically, flowed down the sides of the Continental Divide. On the South Boulder the stream apparently follows quite closely the bed of the old glacier, but the central glacier, which formed the Frazer Valley, had so many tributaries that lateral and medial moraines have influenced the course of the river to such an extent that the exact channel of the old central glacier cannot now be definitely located.

To ascertain whether the rock conditions were favorable for tunnel driving, the State Geologist, Professor George, made a detailed study of the rocks exposed along the line of the tunnel and for a considerable distance north and south of it. He describes these rocks in his report as a complex of gneiss, granite and schist, and as a result of his study came to the conclusion that there are no structural features evident that will interfere with tunnel construction. There are a number of lakes on the side of the mountain almost immediately over the tunnel, and while soundings have not yet been taken in them, there is every reason to believe that they are simply glacial scoops and will not in any way affect the rock underneath or the amount of water in the tunnel, which will pass 1,000 feet below them.

The west portal of the tunnel, as now located, starts near a ridge of rock, but as the ground rises very slowly toward the east, a number of test pits were sunk to test the depth of the morainic material on the somewhat flat ground between Frazer River and Buck Creek. The influx of water prevented the sinking of some of these pits to bed rock, but enough information was obtained to show that it is very improbable that the old glacial channel behind this ridge is deep enough to reach the roof of the tunnel.

At the east portal, solid rock in place is in plain sight for thousands of feet, so that there will be no reason for wasting time drilling test holes, and work on the approach cuts is now under way.

On the line of the Moffat Railway, the United States Geological Surveys only extend a short distance west of Tolland, but as the main range for a considerable distance does not vary much in composition, the rocks exposed at that point and to the north and south, which have been carefully studied by the survey, show that the range is principally composed of the following rocks in the order named: Quartz-biotite schist, hornblende schist, gray foliated gneiss and light to dark gray granite, with some intrusive dikes of monzonite porphyry. The mining engineer would roughly class the rocks in the main range as metamorphic granite with some granite intrusions. In some places the changes in the original sedimentary rocks, caused by heat and pressure, have completely destroyed all traces of sedimentation, while in others the old bedding planes can readily be distinguished.

The present terminus of the Denver & Salt Lake Railway is at Craig, 255 miles from Denver, but the completion of the Moffat Tunnel will reduce this distance 23⅓ miles and eliminate 27.6 miles of 4% grade over the mountain. The highest station on the railway is Corona, on the summit of the Divide, an elevation of 11,660 feet, and the highest point on the line when the tunnel is completed will be the apex in the center of the tunnel, an elevation of 9,249 feet, thus affording a reduction in vertical rise of 2,411 feet.

The total distance from portal to portal is 32,150 feet, or 6.09 miles, which will make it the longest railway tunnel in North America; but this length is exceeded by five railway tunnels in Europe, one of them, the Simplon, being double the length of the Moffat Tunnel.

The railway tunnel will be U. S. standard size, 16 feet wide by 24 feet high, to the intrados of its semi-circular roof.

The water tunnel will be approximately 8 feet high by 8 feet wide, and the center lines of the two tunnels will be 75 feet apart.

While these tunnels, when completed, will be separate and distinct from each other, they will be driven simultaneously and advantage will be taken of their proximity in many ways to increase the rate of speed in driving, improve the ventilation and increase the comfort of the workmen.

Opposite the tunnel portals, the valley of the South Boulder is 145 feet higher than the Frazer River Valley (see Fig. 1), and to reduce the fill on the approach to the west end of the tunnel, this portal is located 113 feet lower than the east portal. To equalize this difference in elevation, the west end of the tunnel rises on a grade of nine-tenths of one per cent, while the eastern half has a grade of only three-tenths of one per cent, the elevation of the eastern portal being 9,205 feet and of the western portal 9,092 feet.

A question often asked is, "How can the pioneer tunnel be utilized as a water conduit to bring water from the Frazer River to Denver when the eastern portal is 113 feet higher than the west? A glance at Fig. 1 will show how this is accomplished.

When the pioneer and railway tunnels are completed, all of the crosscuts between them will be bulkheaded close to the side of the pioneer, and the inner ends of the crosscuts will then become storage rooms for track tools and supplies as well as places of refuge from passing trains for the repair gangs.

The dotted lines show the prolongation of the grade in the eastern half of the pioneer tunnel to the surface on the

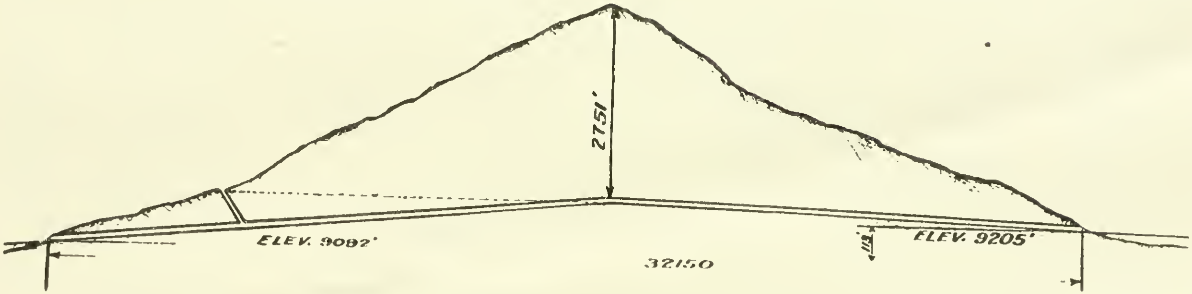

FIG. I.

WEST

EAST

Diagramatic sketch of vertical section through tunnel, showing difference in elevation between East and West Portals and water intake incline.

western slope. From this point an incline will be driven to intersect the pioneer tunnel, the outer end of which will then be bulkheaded. When this is done, the incline and the pioneer tunnel together will form an inverted siphon which will have the same hydraulic grade line as if the eastern half of the pioneer tunnel had been continued through the mountain to the western slope on a grade of three-tenths of one per cent.

In the pioneer tunnel system of driving, which the contractors will employ, the construction of the water tunnel will not increase the cost of the undertaking but, on the contrary, will probably lessen it.

The use of a pioneer or outside heading in tunnel driving is an old, well established device, which has been successfully employed in the 12 mile Simplon Tunnel in the Swiss Alps and the 5 mile Rogers Pass Tunnel in British Columbia. Excellent illustrated papers on the construction of the Simplon Tunnel are published in Vol. 140 of the proceedings of the Institution of Civil Engineers and in the Engineering News, Vol. L., Nos. 7, 8 and 9. A description of the methods employed in the construction of the Rogers Pass Tunnel is given in the Transactions of the American Society of Civil Engineers, Vol. 81.

The following advantages are claimed for this system of tunneling:

1. A very high rate of speed can be maintained in the pioneer tunnel because its progress is not impeded by the operations involved in constructing the main tunnel.

2. As the heading for the railway tunnel is driven by crosscuts from the pioneer tunnel, it can be extended in two directions simultaneously, thereby doubling the usual rate of progress.

3. As the pioneer tunnel is necessarily a considerable distance in advance of the heading and enlargement workings, it gives advance information regarding the ground to be encountered in driving the Railway Tunnel, thereby giving ample time to prepare for any unusual conditions which may be encountered.

4. In wet ground the pioneer tunnel drains the country through which the main tunnel is to be driven, thereby facilitating the work and adding greatly to the comfort of the workmen.

5. When a section of the heading is completed, drilling for its enlargement to the size of the railway tunnel can be carried on by any required number of drills operated in the *heading*, thereby rendering any desired rate of progress possible.

6. As the drill holes for enlarging the headings to the size of the railway tunnel are spaced in rings about five feet apart, these rings may be drilled hundreds of feet in advance of the enlargement. After charging the drill holes, five or six rings can be fired in quick succession by electric delay fuses, thereby giving the compressed-air loading shovel 25 or 30 feet of broken ground to work on at each move.

7. The pioneer tunnel affords free access for men and materials to all parts of the heading and enlargement workings at all times.

8. All pipes for ventilation, compressed air and water can be carried in the pioneer tunnel in a safe and convenient location, where they are undisturbed by the enlargement operations in the railway tunnel. Ventilating problems are greatly simplified by this arrangement, as the ventilating pipe is safely housed and can be used for either the exhaust or plenum systems, or for each system alternately.

9. When the plenum or pressure system is preferred, as is generally the case, the pioneer tunnel itself can be used as an air conduit by placing two air-tight doors a train length apart, at the outer end of the bore. By this means, air can be carried as far as the crosscut used for delivering muck from the pioneer tunnel, and headings into the main tunnel cars and distribution made from that point by means of pipes leading to the different points as required.

10. Utilizing the pioneer tunnel as an air conduit would obviate the purchase and placing of five miles of large and expensive ventilating pipe. When 24,000 cubic feet of fresh

air per minute is being used, the air velocity in the pioneer tunnel would only be four and one-half miles per hour, a rate which would in no way interfere with the comfort of employees when passing through the pioneer tunnel to or from their work in the headings.

11. The great advantage of this system of tunneling is that the work in the pioneer tunnel and heading can be pushed to the limit without interference or hindrance from the operations incident to the enlargement of the heading to the size of the railway tunnel, and at the same time, by spacing the crosscuts to the main bore at whatever intervals experience in the specific case shows to be necessary, the progress in the railway tunnel can be made equal to that in the parallel pioneer tunnel.

12. The interest charges on the present tunnel bond issue, in round numbers, amount to $1,000 a day, and as no income can be derived from the tunnel until it is put into actual use, it is easy to see that the greatest possible expedition in the construction and completion of the tunnel is desirable, hence the speed and other incidental advantages of the pioneer tunnel system will be utilized to the utmost, as every day gained in the completion of the work means a saving of $1,000.

The plans and specifications for the Moffat tunnel called for bids on a unit basis, to be opened on September 12th. Ten bids were submitted but only one of them was in accordance with the specifications. This bid was not only high but contained some conditions which were not desirable, so that all of the bids received were rejected. Discussion with the bidders showed that their estimates were exceedingly high for two reasons, the first being the exorbitant charges demanded by the bonding companies, and the second, the large amounts which each bidder had added to his estimated cost for unforseen contingencies.

Colorado has a state law which provides that contractors on public work must give bond for the faithful completion of the work to the extent of one-half its total cost. This, in the case of the tunnel company, meant a bond for three million dollars, for which the bonding companies asked a premium of $180,000, in addition to which they insisted that the contractor should have assets or financial backing to the extent of $1,000,000.

These terms, of course, were practically prohibitive because if a man had a million dollars he would be very apt to find a much more congenial occupation than tunneling. The addition of sums ranging from one-half a million to a million dollars for unforseen contingencies to most of the bids was probably only business prudence, but as the contingencies were exceedingly remote, it was finally decided that it would be better for the commission to assume the contingencies, as there was not more than one chance in a hundred that they would ever eventuate, than to pay for them to the contractor, whether they eventuated or not. Therefore, the Commission assumed the risk of the stoppage of work through causes beyond the control of the contractors and the striking of flowing mud or hot water in the construction of the tunnel in such volumes or temperatures as to require special drainage or cooling devices.

They then called for bids on a fixed fee, profit-sharing basis, in which the unit costs were estimated to be $5,250,000 and the time required for the completion of the tunnel forty-six months, with $1,000 a day bonus for every day the work was completed in advance of forty-six months. On this basis the bidders were asked to name a fixed fee and the minimum to which this fee could be reduced in case of their failure to perform the work within the specified cost and time. This plan met with a quick response from Ulen & Company, Hitchcock & Tinkler, J. A. McIlwee and Peter Seerie, the lowest bidder being Hitchcock & Tinkler, who were awarded the contract.

Under its terms they will receive a fixed fee of $140,000 plus one-half of the amount saved in the construction cost of the tunnel below $5,250,000, a bonus of $1,000 a day for the completion of the work in less than forty-six months, and a penalty of $1,000 for each day that time is exceeded.

This arrangement is practically the opposite of the cost-plus system which was so thoroughly discredited during the war, as, under the cost-plus system the higher the cost the greater the commission to the contractor, while under the fixed fee and bonus system, the *less the cost* the greater the profits of the contractor.

Hitchcock & Tinkler have been associated together for twenty-five years with various companies, and Mr. Tinkler has just completed the excavation of the 18-mile tunnel on the Hetch Hetchy project for the City of San Francisco. In addition to this, they have built over fifty tunnels, among them fifteen of the tunnels on the Moffat Road, and they also have built the big dam at Nederland and another at Creede.

TUNNELING

Generally speaking, small size tunnels are driven full size at a single operation; medium sized tunnels, where the roof is too high to be reached from the floor, are driven by what is known as the "bench method"; while the largest tunnels are driven by enlargement from a top, center, side or bottom heading, the position of the heading being determined by the character of the rock and amount of water encountered.

Recently, however, owing to the great improvement in rock drills and explosives, there is a tendency to drive larger tunnels by both the "single heading" and "bench methods". The 18-mile Shandaken Tunnel, which is now being completed as an addition to the New York Water Supply System, is 10 feet 3 inches wide and 11 feet 6 inches high, has been driven full size at one operation. The Southern California Power Company, in their 6-mile Cascado Tunnel, which is 20 feet wide and 20 feet high, is driving it with the use of a single bench. This necessitates drilling holes 20 to 22 feet in depth and has been so successful that they are now making from 420 to 470 feet a month in each heading.

The great height of the Moffat Tunnel as compared with its width, does not lend itself to this system of tunneling, in

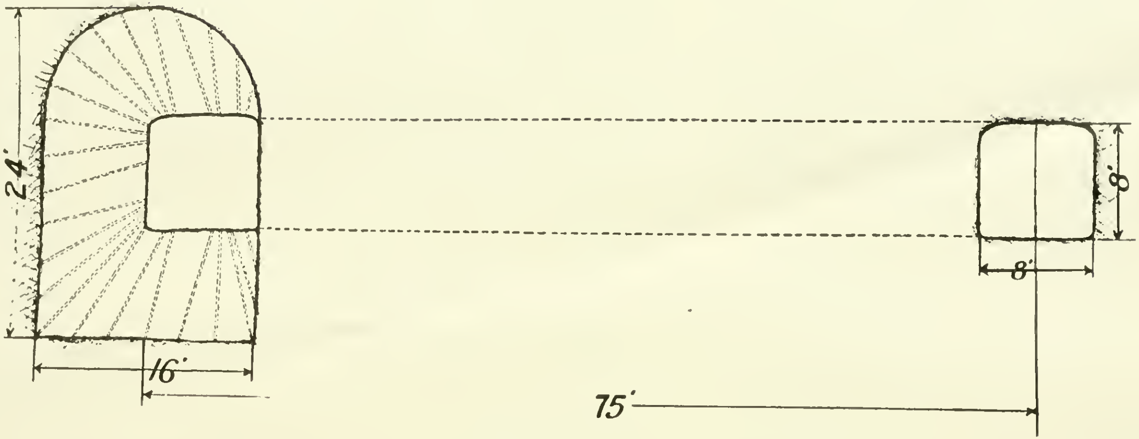

FIG. 2.

Vertical section through Railway and Pioneer Tunnels. Position of crosscuts shown by dotted lines.

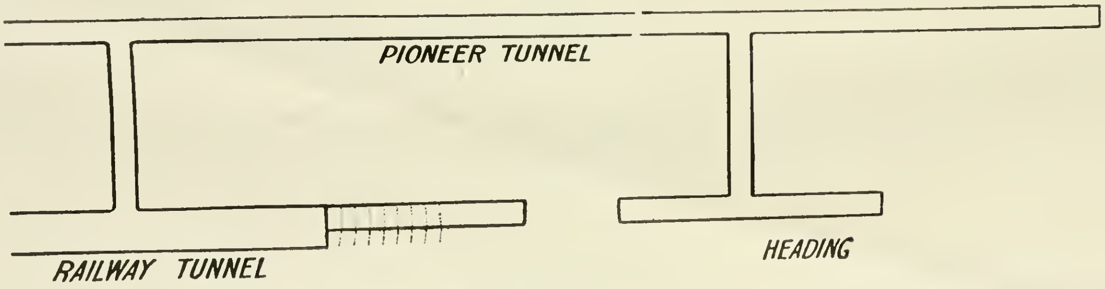

FIG. 3.

Plan of Railway and Pioneer Tunnels showing relative positions of crosscuts and heading.

addition to which the rapid growth of Denver will at a very early date require an additional water supply, which can most conveniently be obtained from the Frazer River on the Pacific Slope. Therefore, for the benefit of all concerned, it was easy to see that the pioneer tunnel system was best adapted to the conditions and requirements of the case.

In this system, the size and form of the pioneer tunnel is determined by the character of the rock encountered, the best cross-section being the one that will give the highest rate of speed consistent with economy. In the pioneer tunnel at Rogers Pass, where exceptionally favorable conditions for driving existed, speeds ranging from 600 to 900 feet per month were attained.

The main tunnel heading is not driven from the railway tunnel, but by cross-cuts from the pioneer tunnel, as shown on Fig. 3, therefore, the heading can be driven simultaneously in opposite directions from the intersection of each crosscut with the line of the main tunnel. From this it follows that the heading may be driven with smaller crews and more economical methods and still maintain the same high rate of progress as in the pioneer tunnel.

When the rock is sufficiently hard to stand what is known as "ring shooting", a ring of holes, as shown in Fig. 2, is drilled from the heading to the outline of the main tunnel. The distance between these rings is determined in a measure by the hardness of the rock, but it is usually about five feet. As there is neither travel nor transportation in the completed portion of the heading, drills can be set up at intervals and holes drilled hundreds of feet in advance of the enlarged portion. Delay electric fuses have recently been perfected so that their timing is reasonably accurate and certain, and in blasting operations in the railway tunnel the first or outer ring is charged with explosives fired by No. 1 delay, the second by No. 2, etc., until five rings are loaded. This method is more akin to underground quarrying than mining, as the blasting in each ring breaks into an open face as the charges in the successive rings explode after each other in rapid succession.

The rock exposures over the mountain and the experience gained in driving the Roosevelt and Laramie-Poudre tunnels through similar rock and at nearly the same elevation, indicate that it is probable that not over five per cent of the tunnel will require support, and where this is necessary only the best grade of Oregon fir timbers will be used.

The cars used in the railway tunnel construction are the usual side-dump contractors' type, strong enough to withstand the impact of the heavy chunks of rock dropped into them from a cubic yard steam shovel. Cars of this size would be altogether too large and heavy for use in the pioneer tunnel and center heading, where lighter cars of from 18 to 25 cubic feet capacity are generally preferred.

During and since the war the scarcity of labor and high rate of wages have brought about the introduction of mucking machines designed for use in small tunnels like the Pioneer.

These machines are of three distinct types, the cheapest and simplest form being a scraper drawn back and forth with a wire cable operated by a small portable, pneumatic hoist. This operation is known as "scraping" or "slushing", and the material is dragged up a metal lined incline into the car by these scrapers.

The second class are diminutive compressed-air or electric actuated shovels with some provision for shortening or jack-knifing the boom so that the shovel can be rotated in a narrow space.

The third class is really a combination of the first two, in which the metallic incline leading up to the car is replaced by a conveyor belt, upon the lower end of which the muck is lifted mechanically with a scoop or shovel.

Each of these types is now represented by highly developed machines, the operation of which is in every way satisfactory.

In both the railway and pioneer tunnels the muck trains will be hauled by electric locomotives operating on the usual trolley system, but as the trolley wires cannot safely be carried nearer the face than 400 or 500 feet, the locomotives will carry a storage battery, from which they will receive current to run from the end of the trolley wire to the face.

A great many very elaborate experiments have been made to determine the exact amount of air required for each man in the face, but owing to the fact that the fresh air which is being driven into the heading does not force the products of explosion back in a solid mass, but mixes with them by diffusion, a greater quantity of air than is theoretically required is extremely desirable. Observations made in seventeen tunnels in operation showed that each heading should have 3,600 to 4,000 cubic feet of air per minute to provide not only for pure air in the face, but to force back the products of explosion and drive them out of the tunnel in a reasonable time.

For ventilating purposes, fan blowers, except for very short distances, should never be used, as the amount of air delivered is in inverse proportion to the length of pipe and consequent frictional resistance. Force blowers, preferably of the cycloidal type, should always be installed, as the amount of air delivered at the face from these machines is constant, no matter how great the length of the pipe, though of course the power required to drive them increases with the length of pipe and consequent frictional resistance.

Both air compressors and ventilating blowers will be installed on the multiple unit system, thereby affording ample assurance against breakdowns. Three or four small machines will of course cost somewhat more than one large machine of the same capacity, but when the work is completed their salvage value will be very much greater.

Electric power to operate all machinery at both portals, will be furnished by the Colorado Power Company at their wholesale schedule. The power requirements will be about 2,000 H. P. and with a 65% load factor the resultant rate will be one cent per kw-hour.

The Moffat Tunnel Commission has recently purchased from Wm. Ainsworth & Sons, a special triangulation transit reading to 10″, but as the tunnel is on a tangent and the line over the mountain can be carried in four or five sights, no special surveying problems are involved.

Due to the great elevation of the mountain under which the tunnel passes, ventilation by means of an air shaft extending from the apex of the tunnel up to the surface, cannot be considered, therefore, electric haulage through the six-mile bore becomes a necessity. As the freight and passenger trains arrive at the tunnel portals, the locomotive fires will be banked and the entire train, locomotive included, will be pulled through the tunnel by a powerful electric locomotive.

About 230 men will be employed at each end of the tunnel and as their efficiency depends on their experience and skill, every available means will be employed to retain them in continuous service by doing everything possible to promote their safety, health and contentment. Complete waterworks and sewerage systems, the latter discharging into septic tanks, have been installed at both ends of the tunnel. A large steam heated change and dry room will be erected at each portal, where the men coming off shift will be expected to remove their working clothes, take a shower bath and put on street attire before going out into the open air. Warm, comfortable bunk houses are now being erected for all of the employees and the mess-house will contain the latest devices for high class cooking and quick service. A small hospital will be erected at each portal and the attendant surgeon, in addition to his other duties, will be expected to look after the sanitary welfare of the camp.

For the amusement of the men when off shift, a recreation building will be erected containing a reading room, billiard room and an assembly hall equipped with a loud speaking radiophone and moving picture machine.

Hard times on farms and the decline of mining, due to the low price of silver, have combined to send to the tunnel an exceptionally high class of workmen, and with the system and equipment described there is every reason to expect that the tunnel will be completed within the estimated time and cost.

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THE RELATION OF COMPOSITION, COLOR AND RADIATION TO LUMINESCENCE IN CALCITES

By Dr. William P. Headden.

(Read at a meeting of the Colorado Scientific Society, October, 1923)

Articles previously published * enumerate a number of facts relative to the deportment of calcites but offer no explanation of them.

It seems to be a very rare thing to find, in nature, a pure calcic carbonate in the sense that it contains no other base, even in extremely small quantities, than calcium oxid. We may as well at the outset state that the quantities here had in view may be in millionths. In fact, it is not practicable for us to handle quantities large enough to bring these minute quantities of admixtures within the range of our ability to identify them. Samaria was detected in various forms of calcic carbonate by the use of the phosphorescent spectrum emitted under the influence of the cathode ray when no more than one part of this earth was present in a million parts of the mineral.

The difficulties are very greatly increased and the probabilities of success in any attempt to find, by analytical methods, a satisfactory explanation lessened, by the fact that the elements involved are very difficult to detect and quite impossible to separate. Further, the elements here concerned

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* "Some Phosphorescent Calcites from Fort Collins, Colo., and Joplin, Mo." American Journal Science, April, 1906.

"Phosphorescence and Luminescence in Calcites." American Journal Science, September, 1923..

"Deportment of Calcites Toward Radium Emanations." American Journal Science, September, 1923.

occur in association with each other so that we cannot be certain whether we have the effect of an association or are dealing with the properties of an individual element. Certain colorless earths in the presence of praeseodymic or neodymic oxids become luminescent in the cathode ray, and something similar may happen in the luminescent phenomena that we wish to present.

We are tacitly assuming that there is some analogy if not closer relationship between the deportment of these calcites when insolated or heated, and when bombarded by the cathode ray or the radiations of radium. This assumption is probably not justified, at least in the measure that we are apt, because of our ignorance of the facts in the case, to apply it. I really have no means of definitely knowing that there is or is not a fundamental difference in these cases; i. e., bombardment by the cathode rays, by the beta and gamma rays, and by the sunshine, but the resultant effects are different having but one thing in common, that is, that the calcite is rendered luminous. The light emitted differs in color and in its duration. The cathode ray produces an orange colored luminosity; the beta and gamma rays orange or yellow; the alpha a very slightly colored, if not a white one. The sunlight produces usually a yellow, in some instances almost a white light. Heating produces in the natural specimens usually a salmon color, often an orange and sometimes other colored luminosities. These are some of the difficulties, not to say perplexing uncertainties, of observation which should be plainly stated and always borne in mind. The uniformity in the effects of the cathode ray, with all the samples that I have seen under its action, seems to suggest that this reaction is due to some fundamental property, probably of calcium itself. The same is true of the X-ray. Every sample of calcic carbonate, also of calcic oxid that I have tested (about forty) luminesces with an orange light; only one has phosphoresced under the X-ray.

The phenomena of luminosity excited by different causes in the same, as well as in different subjects, are themselves complex and this again renders the task of finding the definite cause of any of them difficult.

The first general assumption is that it is due to composition just as naturally so, as we suppose, that color is due to composition. For instance, we say that the chromates are yellow or red; copper salts blue; nickel salts green, etc., and are, for the most part, satisfied with these statements though they are only statements of what our knowledge of their composition and sense of sight testify. A common substance, sulfid of zinc, when pure, does not exhibit phosphorescence after exposure to sunshine but if it is only slightly contaminated with alkaline chlorids or sulfids of some other metals, copper or manganese for instance, it exhibits this phenomenon strongly. These instances, which could be multiplied very greatly, are mentioned merely to justify, in a measure, the very general assumption that these phenomena are dependent upon the composition of the phosphorescing substance. When we approach the subject a little more nearly, we find that it is seldom the case that a pure salt possesses these properties but that there is almost always a slight admixture of some foreign substance which renders the mixture sensitive to the action of light, either the ordinary visible or to ultra-violet light. There are exceptions to this statement, calcic tungstate and baricplatinic cyanid for instance. In artificial compounds the sensitizing agent is very frequently manganese. In the case of the zinc sulfid other substances than manganese, such as copper and the chlorids of the alkalis, are mentioned as imparting this property. There is, at least, one exception to the statement that this property depends upon the presence of some impurity serving as a sensitizing agent even in preparations made in the dry way. Dr. W. S. Andrews, in The American Mineralogist, Vol. 7, p. 21, 1922, describes a cadmium phosphate that phosphoresces when exposed to the ultra-violet light of the iron spark. He states: "This interesting compound may be made by fusing strictly C. P. basic cadmium phosphate in a porcelain crucible. Dr. Andrews kindly sent me a sample of this phosphate and it is undoubtedly the salt $H_2Cd_5(PO)4+4H_2O$, which requires 8·98% water and 28·00% P_2O_5. I find 9·26% water and 28·10% P_2O_5. If this cadmium phopshate be really chemically pure, in the sense that has been indicated in a preceding paragraph, it is a very interesting case, for it definitely fixes this property as resident in the simple base of the salt and is not dependent on the presence of a different element which may possibly form a complex base and sensitize it.

It is perfectly proper to raise the question as to the comparability of these artificial compounds with natural ones. The former are mostly the products of fire processes, whereas the natural compounds, at least the ones with which we are concerned, owe their origin to deposition from solution. The exciting agent, too, may be very different. In some cases, however, they are identical. Sulfids of zinc, of calcium and of barium, prepared in the proper manner, i. e., in the dry way, become prosphorescent on exposure to sunshine, on insolation. This is a different thing from a luminosity, whether it be phosphorescence or luminescence, produced by the cathode ray, or the ultra-violet light of the iron spark, or by the X-ray, or the radiations of radium.

In the case of the cadmic phosphate we have no impurity, and yet it phosphoresces in the ultra-violet light of the iron spark with a white light. Dr. Andrews also sent me a sample of this fused cadmic phosphate. I tested it for its responsiveness to sunlight. It responds quite readily, giving a white phosphorescence lasting, in some of the small lumps, 45 minutes, but only about 8 minutes in the powdered material which had been dried at 100° C. for 3 hours. This salt responds to sunlight, also to the ultra-violet light of the iron spark and it contains but one metallic oxid whereas the other substances exhibiting this property contain two, one in small, if not minute, quantities dissolved in a salt of the other. The pure cadmic phosphate phosphoresces in the ultra-violet light of the iron spark with a pure white light, but if manganese be present the light emitted is red. In this case the manganese causes the red color in the phosphorescence, but is not necessary to the production of luminescence.

In these cases the question regarding the part played by the impurities presents itself, also that of the uniform necessity of their presence to the appearance of the phenomena. Again we are not sure that these artificial products are comparable to natural ones of entirely different composition which also show luminescence under some conditions, but which may be due to other causes.

The artificial luminescent products are obtained by heating the proper mixtures to from 800° to 1200° C. The carbonates in which I have studied these reactions lose their most striking characteristics at a temperature not exceeding 400° C., while they retain others at the highest temperature that I could produce with a blast lamp maintained for 30 minutes. Of course the carbonates were decomposed at this temperature and new reactions may have been established; this seems doubtful, for samples heated to 400°, 600°, and 800° C., reacted the same as those that had been heated over the blast lamp, though the color and composition of the latter had been changed. We insist that some very radical changes had been effected in all of these samples because some of their properties had been destroyed. The most interesting changes had taken place below 400° C., a temperature that left the chemical composition wholly unchanged.

Another line of investigation led to the interesting result that we could restore the properties of which we had deprived these samples. The composition remained unchanged throughout the experiments and the same samples were used. For instance, a yellow calcite which showed a luminescence when heated to 110° C., and became phosphorescent when exposed to a bright sunshine became colorless when heated to 400° C., and would then show no luminescence on heating or phosphorescence when exposed to the brighest sunshine for any length of time, could be made to resume a yellow color and all of its former properties. Further, we found that colorless, unresponsive calcites would, under certain conditions assume a yellow color and become responsive to both sunshine and heat.

There is another series of properties but these remained unchanged throughout and were uniform for all samples tested. All samples of calcites that I have seen subjected to cathode rays give an orange phosphorescence, and all samples of calcic carbonate or calcic oxid that I have seen bombarded by the X-ray give an orange luminescence. Some samples, yellow ones, may exhibit a persistent phosphorescence, but these samples can be deprived of this property while that of luminescence remains.

These facts have been given to present the question of composition as fairly as possible and to show its importance. Certain impurities, very frequently manganese, render some substances responsive to certain agents, i. e., will cause them to give out light for a brief and sometimes for a longer time. The didymic oxids are reputed to possess this property in a noteable degree. On the other hand, it is evident that in the case of the calcites this is not a satisfactory explanation for the phenomena which present themselves, and it is evident that other factors play a part.

The question is, what is the part played by the accidental constituents in the calcites?

We assumed that the color as well as the property of phosphorescence on insolation is dependent upon the composition, but we have found that we may leave the composition unchanged and destroy both the color of the yellow calcite and its ability to phosphoresce and restore them to this identical sample, for which purpose we use the radiations of radium.

Our present purpose is to study the relation of composition to these luminescent properties, and to ascertain whether there be any fixed and necessary relations or not.

The difficulties in this study are very great. It is supposed that exceedingly small quantities of an accidental constituent may have a great influence upon the deportment of a sample; this quantity may be so small that we cannot manipulate a sufficiently large quantity of the sample to enable us to establish the presence and identity of this accidental constituent. I know of no way to answer this objection to any work that may be offered. In other words, this investigation by analytical methods can only go to its limit and we must abide by the results that it presents. I have used in my efforts to see if I could find any correlation between composition and the luminescent properties of calcites from 30 to 2000 grams on which to make my determinations. In an extreme case I used 25 pounds. I shall try to present these results without concern about the contradictions that may present themselves.

The samples on which my first observations were made remain the very best material that I have yet found; namely, material from Joplin, Missouri. The facts in this case are as follows: A small cleavage piece may show as large a range of properties as a large collection of samples. A portion of it may be yellow, another transparent and purple, or transparent and colorless, or white and opaque. This is the range in colors and it presents the whole range in properties. The luminescent properties shown are as follows: the yellow has the greatest range but in some respects reacts less intensely than the purple. The most striking and chief property of the yellow is its responsiveness to sunshine. Of the Missouri samples that I have examined, it is the only one that shows this property, i. e., of phosphorescing for a long period after insolation. A second property is that it phosphoresces when gently heated. The former phosphorescence is yellowish, the second is salmon colored; it also phosphoresces under the influence of X-rays. It also shows luminescence varying in duration and brilliancy with the exciting cause, and in common with other calcites gives an orange colored phosphorescence under the action of the cathode ray. It is not responsive to the ultraviolet light of the iron or subaqueous aluminum spark, but is responsive to the light of the molybdenum arc and of burning magnesium. The color of the phosphorescence, in this case, is more nearly white than that excited by the sunshine.

I have never seen the purple Missouri calcite respond to sunlight or show any degree of phosphorescence under any condition except under the action of the cathode ray. I have often exposed pieces partly yellow and partly purple. In such cases the yellow became phosphorescent and the purple did not; neither did the colorless, transparent, or the white opaque when such was present in the samples. This remark also applies to the phosphorescence excited in such pieces by the X-ray. While I can make no stronger statement of the fact than I have just made concerning the occurrence of phosphorescent and non-phosphorescent material in the same small cleavage piece, I wish to emphasize it by calling attention to it as these were parts of individual crystals, and while there were differences in color corresponding to differences in deportment under the influence of sunshine, it would scarcely seem probable that the chemical composition of a crystal could vary so irregularly as these colors do. Still, too much weight must not, at this time, be attached to this view, for these crystals show definite lines of growth whereat the deposition of yellow calcite ceased or began. This means, that some crystals have an interior yellow portion surrounded by a later growth of colorless or slightly violet portions, while in others only an exterior shell of greater or less thickness is yellow. If these lines of growth were of themselves not satisfactory testimony in regard to this point, we have other proof that this change marked a period of growth, to wit: the interior yellow crystals sometimes carry a crop of chalcopyrite crystals on their surfaces which must have grown at the end of one period and probably before the beginning of the subsequent one. It would seem clear that these changes in color correspond to changes in the composition of the depositing solution. I will remark in this place, that this conclusion is based upon the assumption that no other condition than change in composition could determine this change in color, which may prove not to be the case. We shall come back to this point but from a different angle.

While all the yellow portions respond to such a sunshine as we usually have, all of the other portions fail to so respond. There are other reactions which they have in common, but not in the same degree.

The phenomenon of luminescence is even more complex than that of phosphorescence. By the former we mean the emission of light by a substance under the action of some exciting agent which begins and ceases simultaneously with the beginning and ceasing of the exciting agent. We cannot instantaneously change the temperature of a sample from 0° to 300° C., or from 300° C. to 0°, and so to make luminescence excited by heat appear and disappear as quickly and as often as we may desire in a given time, but we can interrupt the activating current of an X-ray machine and the light emitted by the sample will appear and disappear as often as we close and open the circuit.

We shall ask you to consider, in a general way, the three kinds of Missouri calcite, white, yellow, and purple, taken from the same crystal in their luminescent behaviour toward heat. First, they all show a two-phased luminescence, one below 110° C., and a second one at about 300° C., or a little above but below 400° C. That of the white is very brief and inferior even at 300° C.; that of the yellow at the lower temperature is very decided, and at 300° C. has an average duration of 18 minutes, while the purple at 300° C. presents an exceedingly bright orange luminescence which in thirty minutes changes to bluish white and continues visible in a partially darkened room for 2½ hours. All of the samples are colorless after such heating and all now have the same behaviour toward sunshine and heat, namely, they are dead. Further they now have the same behaviour toward the cathode and the X-ray. They phosphoresce under the action of the cathode ray and luminesce under that of the X-ray with the same color.

We have not changed their composition but we have rendered them alike colorless and equally unresponsive to the action of sunlight and heat and left them a common deportment toward the cathode and the X-ray. The composition has not been changed unless some gaseous constituent has been eliminated, of which we have no proof. Such a test would be valuable, but I have not the facilities necessary to make it.

We have in these three samples, pieces cleaved from the same crystal, the widest range of properties that we have found in this mineral; to enumerate them would be confusing rather than otherwise. It would seem that the facts already given, though given in an incidental manner, are sufficient to show very clearly that we have to do with something, perhaps not independent of, but certainly distinct from the composition of the mineral.

While I entertained no sanguine hope of obtaining any definite and satisfactory results by making analyses of different samples of the mineral, I have made the effort. Of course the yellow calcite from Joplin, Missouri, seemed the most promising point of attack. This sample was analyzed a number of years ago, and I use the analysis which has been published before because I do not know how to make a better one. The lime and carbon dioxid make up 99·690 per cent of the mineral, and as all the calcites discussed are samples of the pure mineral, these two constituents and also magnesia for the most part will be omitted. Only the accidental constituents will be given.

Yellow Calcite From Missouri Strongly Phosphorescent on insulation

		Percent
Rare earths		0·032
Cerium group	0·019	
Yttrium group	0·013	
Magnesic oxid		0·113
Manganous oxid		0·045
Ferrous oxid		0·046
Zinc oxid		0·014
Copper oxid		none

In this case as thorough an analysis was made as I know how to make, and traces only were found of the following substances: sulfuric acid, phosphoric acid, chlorin, strontium, aluminium, chromium, ammonium and sodium. For these determinations large quantities of the mineral were taken up to 500 grams for an analysis, and even 25 pounds were used to obtain sufficient quantities of some constituents. This statement applies to all Missouri samples.

Some unresponsive calcites, Joplin, Missouri, gave the following results:

No. One		*Percent*
Rare earths		0·0380
Cerium group	0·0206	
Yttrium group	0·0175	
Ferrous oxid		0·0990
Aluminic oxid		0·0053
Chromic oxid		Trace
Zinc oxid		Present
Manganous oxid		Present

No. Two		*Percent*
Rare earths		0·02644
Cerium group	0·0124	
Yttrium group	0·0133	
Ferrous oxid		0·0972
Aluminic oxid		....
Chromic oxid		Trace
Zinc oxid		Present
Manganous oxid		0·0556

No. Three		*Percent*
Rare earths		0·0478
Cerium group	0·0336	
Yttrium group	0·0141	
Ferrous oxid		0·1197
Manganous oxid		0·0635
Zinc oxid		Present

No. Four		*Percent*
Rare earths		0·0310
Cerium group	0·0183	
Yttrium group	0·0122	
Ferrous oxid		0·1392
Manganous oxid		0·0419
Zinc oxid		Present

No. Five	*Percent*
Rare earths	0·0082
Ferrous oxid	0·1134
Manganous oxid	0·1020
Zinc oxid	0·0058

No. Six, Purple		*Percent*
Rare earths		0·0546
Cerium group	0·0397	
Yttrium group	0·0149	
Copper oxid		0·0090
Ferrous oxid		0·0148
Aluminic oxid		0·0076
Zinc oxid		0·0048
Manganous oxid		0·0477
Magnesic oxid		0·0949

Number 5 is a sample of white, opaque calcite from Joplin, Missouri, and is unresponsive to sunshine; the others are transparent colorless or purple samples. The samples from number 1 to 6 inclusive do not respond to sunshine.

There are no differences in composition presented by these analyses on which we can justly base any attempt to explain why the one is and the other is not responsive to sunshine. The responsive and unresponsive samples were made up of parts of the same crystals, the only difference being that the responsive samples are all yellow and the unresponsive ones are not yellow; but we have no reason for attributing this difference to differences in composition. We examined very many samples of this calcite, hundreds of small pieces at a time, also very many large samples and never found an exception to this rule that the yellow alone, in this Missouri material, is responsive to sunshine.

We found only one reason that appears valid for attributing either of the colors in these samples to composition. The reason referred to is the fact that the purple portions show an absorption spectrum identical with the principal lines of a solution of didymia. As this element is actually present in the cerium group I can see no way of disproving the assertion that it is actually the cause of the purple or violet color though we doubt it. On the other hand, the didymic oxids are known to render some other oxids, that by themselves are unresponsive to the cathode rays, responsive to it, but these purple calcites are never responsive to the sunshine. While this fact is suggestive, it proves nothing for the sunshine and the cathode rays are two different things, but the fact that the didymic oxids are known to be sensitizing agents remains suggestive.

I have so far presented this Missouri material for consideration because it is by far the most striking in its characters and presents a definite characteristic whereby we can with certainty distinguish between the responsive and unresponsive material. The yellow alone being responsive, and the yellow is marked by definite lines of crystal growth and is, so far as I have seen, never diffused through the mass as the purple often is.

One must remember that we distinguish very sharply and insist upon the difference between phosphorescence and luminescence, and that the preceding statements concerning the yellow calcite pertain to its phosphorescence. If we consider luminescence, then the yellow is very inferior to the purple both in brilliancy and duration. The luminescence shown by the yellow under the best conditions lasts 18 minutes while that shown by the purple is much more brilliant and lasts for 2½ hours. As in the case of responsiveness to sunlight, the composition gives no evident basis for an explanation. The only distinguishing thing shown by this purple calcite is its absorption spectrum presumably indicative of the presence of dydymia. The purple color seems, in the case of the Missouri calcites, to indicate with certainty this high degree of luminescence just as the yellow indicates responsiveness.

The Missouri calcites are not the only ones that show responsiveness. They are the only ones, so far as I know, in which responsiveness is confined to those parts having a yellow color. There are calcites from other localities that are responsive but not in the same high degree as the yellow Missouri samples. They are of different colors, yellowish, brown or brownish, and colorless. I have a honey-yellow sample, locality unknown, that is not responsive. The color in the different cases is not due to the same causes. This honey-yellow calcite, dissolved in nitric acid and evaporated to dryness, leaves a yellow mass that chars on heating. The yellow color is due to organic matter. We shall consider this sample later from another standpoint for it is an interesting one.

The calcites so far considered are from a single collection and from one locality, given as Joplin, Missouri. The purple and colorless portions are not responsive, the yellow alone are responsive. These statements are true of the Missouri calcites only. There are colorless calcites that phosphoresce on insolation but with neither the brilliancy nor persistency of that shown by the yellow Missouri samples. There are also other calcites, in fact almost all other calcites show luminescence on heating, some of them with a beautiful light, but none of them is comparable to the purple Missouri material.

A vein of calcite traversing the Benton shales near the head of Fossil Creek a few miles from Fort Collins furnished some yellowish samples that after insolation continued to phosphoresce for more than 2½ hours. The original sample was brought to the laboratory and was not collected by myself. We subsequently gathered some of this calcite for general laboratory use. This material responds feebly, and some pieces of it quite well. The better material is yellowish or greenish yellow. The composition of this calcite is similar to those already given, as the following analysis shows:

Calcite, Fossil Creek, Colorado

	Percent
Rare earths	0·0022
Copper oxid	Trace
Ferrous oxid	0·0404
Zinc oxid	0·0009
Manganous oxid	0·0020
Magnesic oxid	0·0920

No attempt was made to separate the rare earths into groups. The oxid had a very light cinnamon brown color; were easily soluble in hydrochloric acid and showed only a faint absorption spectrum for the principal didymium line.

Calcite, Limestone Quarry, Murke, Wyoming

This is an outer zone covering an oblong mass of brown, banded calcite. This zone is a little more than 1½ inch thick, composed of a radiating mass of poorly terminated crystals. The calcite is transparent, colorless. On insolation it phosphoresces for a short time, 2 to 3 minutes, with a pure white phosphorescence.

A second sample from the same source formed an irregular, but almost spherical mass about 7 inches in diameter, composed of concentric layers varying from light brown to almost black in color. The outside layer, a scant inch in thickness, was the lightest and varied some in color; immediately beneath this was the darkest, a very narrow band which was almost black. The whole mass without regard to color phosphoresced, with a white light on insolation for 2 or 3 minutes. This, like the preceding, is a remarkably pure calcite. The analyses of these samples follow in order as Nos. 1 and 2.

No. One	*Percent*	*No. Two*	*Percent*
Silicic acid	0·0151	Silicic acid	0·0154
Rare earths	None	Rare earths	0·0005
Ferrous oxid	0·0055	Ferrous oxid	0·0018
Copper oxid	Trace	Copper oxid	0·0009
Phosphoric acid	Trace	Phosphoric acid	0·0070
Manganous oxid	0·0015	Manganous oxid	0·0143
Zinc oxid	0·0015	Zinc oxid	0·0029
Magnesic oxid	None	Magnesic oxid	Trace
Nickel oxid	....	Nickel oxid	0·0007

The next sample is designated Ingleside, Dog-tooth Spar.

This represents a deposit 6 to 8 inches thick formed between strata of limestone at the Ingleside quarry. The calcite is colorless and transparent. Its deportment has been very disconcerting. It was insolated on September 30, 1922, in an apparently strong sunshine, and it did not phosphoresce. The notes made on that day make special mention of this and add that samples were insolated from 1 to 2½ hours. I have since that had this sample to fail without any apparent reason. Again, it phosphoresces well with a white light but the phosphorescence was of short duration, 3 to 4 minutes.

At the present time I am singling out phosphorescence on insolation from a whole group of luminescent properties in order to present the relation between this phosphorescence on insolation and composition, if such can be proven to exist. It would be too much to say that this phosphorescence is the most important of these phenomena but as it depends upon the sunshine it appeals to us more directly than a phosphorescence produced by the light of the molybdenum arc, or some other artificial agent.

Near the locality last mentioned is another limestone quarry, the Alford-Maxfield quarry, where a yellowish white calcite occurs, also in interstices between the strata of limestones. This has always responded to sunlight with a mild yellowish light, rather brilliant but of short duration.

The analyses of these two samples follow:

Ingleside		Percent	Alford-Maxfield	Percent
Rare earths		0·0023	Rare earths	0·0023
Cerium group	0·00068		Cerium group	
Yttrium group	0·00159		Yttrium group	....
Ferrous oxid		0·0084	Ferrous oxid	0·0007
Copper oxid		0·0001	Copper oxid	0·0002
Zinc oxid		0·0003	Zinc oxid	0·0016
Manganous oxid		0·0428	Manganous oxid	0·0003
Sulfuric oxid		0·0126	Sulfuric oxid	....
Magnesic oxid		0·1924	Magnesic oxid	0·1470
Phosphoric acid		....	Phosphoric acid	0·0267
Silicic acid		....	Silicic acid	0·0030

Reference is made in preceding paragraphs to a honey-yellow calcite from an unknown locality. This sample does not respond to sunlight, that is, in its natural condition. The color is, I believe, correctly attributed to organic matter.

I have another strongly colored calcite, brown, from Barstow, California. This, unlike the preceding, phosphoresces strongly on isolation. In this case too the color is due to organic matter which is largely insoluble in hydrochloric acid. The analyses of these samples are given because the color in each case is due to organic matter and because they show a contrary deportment toward sunlight, the yellow one being unresponsive while the brown one responds brightly for a short time.

Honey-Yellow Calcite Locality unknown	Percent	Brown Calcite Barstow, Calif.	Percent
Quartz	0·8110	Quartz	....
Silicic acid	0·3120	Silicic acid	None
Rare earths	None	Rare earths	None
Copper oxid	0·0040	Copper oxid	None
Ferrous oxid	0·0846	Ferrous oxid	Trace
Zinc oxid	0·0053	Zinc oxid	None
Nickel oxid	Trace	Nickel oxid	None
Manganous oxid	0·2638	Manganous oxid	None
Magnesic oxid	0·0952	Magnesic oxid	Trace
Aluminic oxid	None	Aluminic oxid	0·0570
Organic matter	Not determined	Organic matter	Not determined

The brown calcite from California was analyzed four times and the record is as here given. I surmise that the alumina is associated with its organic matter. The amount of mineral used for the analyses was from 2 to 50 grams.

As previously stated, any attempt to discuss the probable relation between the phosphorescence excited by sunlight and composition will have to be made with certain considerations in mind. The principal one is that these reactions are so exceedingly more sensitive than our manipulations are accurate that our best results may fail us as reliable bases for such discussions. While we willingly grant the possible correctness of this, we still think that the results obtained by analyses when carefully made on a sufficient quantity of material have some real value after all, and that the general conclusions based on such results will be our best approach to the truth.

At the very outset we are confronted by our ignorance of the properties of calcic carbonate. The analyses given (17 of them) show that it is really a rare thing to find a calcite that is anywhere near pure calcic carbonate in the sense or degree that pure is considered in this connection. Our statement of these analyses appears to be in some detail and yet we bunch the rare earths in two groups when we know that these two groups include, at the present time, 17 known elements all of which may be present. But I think that we can quite confidently draw some conclusions from the composition as set forth by the analyses. I think that the analyses include all the elements present except traces of chlorin and sodium, with the addition possibly of ammonium and potassium. We have in some cases tested for these as well as for barium and strontium, mostly with negative results.

We have given first an analysis of a highly responsive calcite and following this, analyses of six unresponsive ones. These seven samples are from the same locality and several of them broken from the same crystals. Our object is not to discuss the composition from a mineralogical standpoint but simply in connection with the responsiveness or unresponsiveness to sunshine; all other excitants are at the present time excluded. All samples are approximately 99·80 per cent pure calcic carbonate and any differences in properties must naturally be sought in the composition of the 0·20 per cent impurities. To speak of extreme differences in the physical properties of these samples would be entirely gratuitous, for so far as we are now concerned they either do or do not respond to sunshine. Still it would be useless to discuss each analysis, so we will simply compare the yellow and the purple. These constitute equally beautiful specimens of the mineral. The yellow has seldom failed to respond to our sunshine and the purple has never responded, even when exposed as a part of the same piece. The size of the piece has never made any difference.

My view is that this is not due to differences in chemical composition. That there are differences of some sort between the samples is evident, and these differences correspond to the differences in color. It is true that the colorless and white opaque portions of these crystals do not respond to sunshine, but to include these would involve further discussion which at the present moment I wish to avoid because it would introduce new complications. The differences in the properties of these portions of the same crystals are not due to differences in composition. It must not be inferred that their composition is identical because they are parts of the same crystal; such is by no means necessarily the case.

In a preceding statement I have referred to the fact that manganic and didymic oxids are known to impart responsiveness to ultra-violet light and to the cathode ray, and it requires some effort to convince ourselves that the phenomena here presented are not analogous. We can demonstrate that pure sulfid of zinc does not become phosphorescent on insolation, and yet we manufacture a sulfid of zinc containing impurities—copper and manganese are very effective—that is used as a phosphorescent paint.

The argument from analogy that these calcites contain small amounts of didymia and manganese or copper and zinc and are for these reasons responsive to sunshine would, in my opinion, be without force. There is something else; every impure sulfid of zinc containing chlorids of the alkalis or copper and manganese does not possess this property.

Our yellow calcite from Joplin, Missouri, contains 0·032 per cent of rare earths, divided nearly equally between the cerium and yttrium groups; 0·045 per cent manganous oxide and 0·014 per cent zinc oxide and no copper. These yellow calcites may be said to always respond to sunshine, that is to our sunshine, to the sunshine of Nevada and of California, but they seem to fail to respond to the sunshine of New York, and an occasional failure may be met with in Colorado, due to atmospheric conditions.

The purple calcite contains of the rare earths 0·0546, with about three times as much of the ceric group of which didymia is a member as it does of the yttrium group, 0·0477 of manganous oxid, 0·009 of copper oxid and 0·0048 per cent of zinc oxid. This purple never responds to sunshine. These samples showing the extremes of responsiveness and unresponsiveness to our sunshine give no evidence that these characteristics depend in any way upon their chemical composition. Even the argument that these properties may depend upon such infinitesimal quantities of these respective elements that they escape detection by our balances does not apply unless it be argued that the element or elements are at present unknown. But so far as the known elements are concerned, the argument based on the presence of infinitesimal quantities will not apply, if it be attributed to didymium or to any other of the rare earths it is included and the unresponsive contains more than the responsive. The same holds for the copper, zinc and manganese.

There is another way of approaching this question of the relation of this phosphorescence in calcites to their composition. Calcites are not the only minerals that show phosphorescence on isolation, but we confine ourselves to calcites and for the present to the phosphorescence excited by sunshine. We shall have something to say about other luminescent phenomena later.

The yellow calcites from Joplin, Missouri, are not the only calcites that show this photophosphorescence. They are only the ones that show it so beautifully and persistently. A yellowish one from Ft. Collins showed the same property but not so brightly for more than 2½ hours against more than 13 hours for the Joplin sample. The Ft. Collins sample contains rare earths, 0·0022 per cent, copper, a trace, zinc oxid, 0·0009 and manganous oxid 0·0020 per cent. The phosphorescence of these samples is similar to that of the Joplin samples, a soft yellow. The impurities in the calcite are the same ones that we find in the Joplin samples but in very much smaller quantities.

So far, the responsive calcites presented have had a yellow color and exhibited a soft yellow phosphorescence. The unresponsive ones have been colorless or purple and we might be tempted to correlate a yellow color with the property of photophosphorescence which is in no manner justified; we might be justified in correlating a yellow color in the calcite with a yellow photophosphorescence if the sample shows any.

Two samples from a limestone quarry in Wyoming are of interest in this connection. These samples show a white phosphorescence, beautiful but brief. These samples present two varieties of the mineral, one a colorless, transparent, radiating mass of poorly terminated dog-tooth spar crystals; the other a brown, banded mass of radiating structure, apparently stalagmitic in origin. The colorless portion contains: rare earth none, copper, trace, zinc oxid 0·0015 per cent, manganous oxid 0.0015 per cent and magnesia none. The brown mass contains rare earths 0·0005 per cent, copper 0·0009, zinc oxid 0·0029, manganous oxid 0·0143 and nickel oxid 0·0007 per cent. The colorless sample contains no rare earths and the brown only five parts per million, but they are both photophosphorescent and that beautifully so for a short time. The manganese is also very low in the colorless, 15 parts per million, whereas the nonphosphorescing calcites from Joplin carry as high as 1020 parts per million.

A transparent colorless calcite in the form of crowded, 6- to 8-inch long dog-tooth spar crystals from Ingleside, a quarry a few miles from Fort Collins, is briefly photophosphorescent with a white light. This calcite contains rare earths 0·0023 per cent, copper 0·0001, zinc oxid 0·0003 and manganous oxid 0·0428 per cent.

Another sample from another quarry, also near Fort Collins, is very brightly but briefly photophosphorescent with a very soft, faintly yellow light. The color of the sample is also faintly yellow. The rare earths in this sample equal 0·0023 per cent, the copper 0·0002, zinc oxid 0·0016 and the manganous oxid 0·0003 per cent.

We have now considered briefly the composition of the yellow photophosphorescent calcites of Joplin, Mo., and that of the purple, wholly unresponsive calcite from the same locality and we find that it does not justify the view that this property depends, at least directly, upon the composition.

Further, that the yellow color is not necessarily correlated to this property, for the colorless calcites are also photophosphorescent. Further, that the composition of these colorless calcites shows no consistent or necessary relation to the property. We have laid stress particularly upon those accidental constituents usually mentioned as sensitizing agents, but no others found show any relation whatsoever to this property.

I shall give two more instances, one that does not and one that does respond to sunshine. A yellow nonresponsive one contains rare earths none, copper 0·0040, zinc oxid 0·0053, manganous oxid 0·2638, nickel oxid a trace. A brown responsive calcite rare earths none, copper none, zinc oxid none, manganous oxid none. Both of these contain organic matter to which the color is due and which, in the case of the brown calcite contains a little alumina. Objection may be made to this pair of samples either by themselves or in consideration with the preceding samples, owing to the fact that we know nothing about the organic matter present. I am perfectly willing to acknowledge that we know nothing about the organic matter or its effects, but it remains clear that the absence of the rare earths in both samples and the presence of manganese in one has nothing to do with the photophosphorescence, for the sample in which the manganese is absent possesses the property of photophosphorescence, while the other in which it is more abundant than usual does not possess it.

All of this only shows that there is no immediate relation between the composition and the property under discussion, it does not exclude the possibility of a mediate relationship.

The property under discussion is not a permanent one; it can easily be destroyed by heat. In this it differs from the property of responding to the ultra-violet light or to the cathode ray imparted to substances heated to a high temperature with the addition of manganese dioxid.

While we can destroy this property by heating persistently, 46 hours, to a temperature of 155° C., or for 20 minutes to a temperature of 250° C., whereby the yellow color will be discharged, we can both restore it to a yellow color and impart the property of photophosphorescence which we will discuss a little later.

I wish at this time to emphasize the fact that we have proved that there is no immediate relationship between the composition and the property of photophosphorescence. Samples containing all of the accidental constituents that we have found may or may not be photophosphorescent.

Fortunately we have found a few samples which do not possess this property and to which we have been unable to impart it. These have remained unchanged both in their color and unresponsiveness to sunlight through all of the experiments in which they have been used. Up to the present time I have found but three such samples; all three are of the dogtooth type and all of the samples are small and from unknown localities. I made an analysis of one of these samples using 50 gs., this amount of material gave me the following results:

Dog-Tooth Spar No. 3
Locality Unknown

	Percent
Rare earths	None
Copper oxid	Trace
Manganous oxid	0·0028
Zinc oxid	0·0020
Ferrous oxid	0·0018
Magnesic oxid	0·1248

The force of the statement that these three samples, this one among them, have remained unchanged in both their color and unresponsiveness through all the experiments in which they have been used, is this that other calcites of similar composition may be both colorless and unresponsive but may be colored and rendered responsive, which is conclusive proof that there is no immediate and necessary relation between chemical composition and these characteristics.

If we accept our analyses as sufficiently exhaustive, which I firmly believe them to be, we have the basis of an interesting explanation of this particular characteristic of the calcites which probably applies to all of the characteristics of this mineral, triboluminescence, thermoluminescence at low temperatures, 60-180° C., easily destroyed, thermoluminescence at 300-400° C., the property being destroyed when the heating is continued until luminescence ceases; in this case the color, yellow and purple alike, is discharged; thermophosphorescence at low temperature, 60-180° C., which is more easily destroyed than the thermoluminescense; photophosphorescence excited by sunshine, destroyed by a temperature of 250° C. maintained for 20 minutes, X-ray phosphorescence excited by the X-ray and destroyed simultaneously with the photophosphorescence, with which it may be identical; an X-ray luminescence and a cathodic phosphorescence. The last two may be fundamental, but different samples vary in their response to these radiations. It may be remarked in this connection that Prof. Nichols of Ithaca, also Dr. Andrews of Schenectady, have failed to obtain X-ray luminescence. If these should prove to be real cases of failure on the part of the mineral to respond, then they are probably not fundamental.

The composition of the different samples whether broken from the same crystal or consisting of different crystals from different localities agrees well in the range of the elements present as impurities. It has been stated that chlorin and the alkalis have generally been left out of consideration, but these are given in one case which is representative of seven of the fifteen samples given. In this case these elements were represented by traces. This range includes the rare earths, copper, magnesia, manganese, iron, chromium, zinc and occasionally nickel, aluminium, sulfuric and phosphoric acids. The relative quantities of the individual impurities present in the different samples show no relation to the responsiveness or unresponsiveness. The purest calcite that we have found is responsive to sunshine, but it unfortunately contains organic matter and with it a little alumina, these being its only impurities. The next purest one is also a responsive sample, briefly so it is true, but brightly responsive. The range of its impurities is less than in any other sample except the preceding and is confined to zinc, manganese and iron—the respective quantities of these being fifteen, fifteen and fifty-five ten-thousandths of one per cent. An unresponsive sample, unresponsvie to sunshine and largely negative in other respects, has a narrow range of impurities but less narrow than the one just cited; it includes zinc, manganese, iron and magnesia. The magnesia alone amounts to 0·1249 per cent, the other three amount to 0·0064 against 0·0030 per cent in the preceding. I do not think that we have any reason for attributing the difference to the presence of the 0·1249 per cent of magnesia, for two others which are responsive have respectively 0·1924 and 0·1470 per cent magnesia, both of these contain small amounts of rare earths, but we have responsiveness in the absence of rare earths and unresponsiveness in their presence. In fact, the largest amount of rare earths is found in the unresponsive samples.

The only conclusion justified by the data presented is that there is no direct relation between the composition and the responsiveness or unresponsiveness of the different samples of the mineral. This is contrary to a generally accepted view and one which I have formerly expressed in offering an explanation for this photophosphorescence.

I have in an earlier paragraph frankly expressed doubts whether there is any direct relation between the color of these calcites and their composition. In an article entitled "Some Phosphorescent Calcites from Ft. Collins, Colo., and Joplin, Mo.," I insisted upon the fact that only the yellow calcites possessed this property and that the white and purple did not possess it, and have elsewhere stated that to find the cause of the yellow color would be to find the cause of the phosphorescence. This was true of the Missouri samples, and also of the only samples from Fort Collins of which we then had knowledge. It is not true of all photophosphorescent samples; some colorless ones as well as some brownish ones possess this property, but it is true that of the Missouri samples only the yellow portions phosphoresce on insolation and most other samples that show this property have a yellowish color. It is a fact that the colors in these calcites can easily be discharged simply by heating them and that to very moderate temperatures, and with the discharge of the color the photophosphorescent property is destroyed. This instability of color is not characteristic of the color of chemical compounds. The chemical composition of the calcite in the sense that we are accustomed to use this term remains unchanged; the calcic carbonate has in no degree been decomposed and the same impurities are present as before, but the color has disappeared and with it the calcite has lost this remarkable property. The more remarkable thing is that we can restore the color and the property; in fact, we can change the colorless photophosphorescent calcites into yellow photophosphorescent calcites and still more remarkable, we can convert colorless and purple unresponsive calcites into yellow responsive ones. Our quest has been to find the cause of this photophosphorescence more particularly than to explain the other luminescent phenomena shown by calcites. I have stated that we have no grounds whatever to predicate an immediate relation as existing between the composition of these calcites and this property but there may be some mediate relationship, but I am quite firmly convinced that it is a matter of atomic structure rather than a matter of composition.

These statements in no way modify that previously made relative to the relation between the yellow color and photophosphorescence, and I still believe that to find the cause of one is to find the cause of the other.

A colorless responsive calcite was made more strongly responsive and colored yellow by radiation. My conception of the change effected is—that in its natural condition the certain arrangement of the electrical elements in the atoms that emit vibrations that produce in us the sensation of yellowness is not dominant enough to produce this effect and the calcite appears to us colorless. But they are so strongly disturbed by a proper sunshine that they can produce a luminosity for a short time. Radiation enhances this arrangement to such an extent that the calcite appears yellow and its power to luminesce has been greatly increased. My idea is that the yellow color is due to the arrangement of the protons.

If I take a piece of this colorless calcite from Missouri which is wholly unresponsive and enclose it in a tube filled with the emanation given off by radium it will glow with an orange color. How long it will continue to glow, I don't know; as long at least as there is any life in the emanation. I have watched it 33 days, which is rather longer than the emanation is supposed to live; on opening the tube it is found to be no longer a colorless calcite but a yellow one with the properties of the yellow calcite which are entirely new to it.

If we take a piece that was yellow but has been rendered colorless by having been heated to 600° C., whereby at least three distinct properties have been destroyed, it will be colored yellow and have its destroyed properties restored. If I take a piece of purple calcite and heat it until it is dead when it will be colorless, and treat it with the radium emanation, it will not be restored to its purple color but will be changed into a yellow calcite with the properties of the yellow calcite which it did not before possess. It is really a new calcite. It is now photophosphorescent and has two stages of thermoluminescense. In respect to the second stage of thermoluminescence its duration exceeds that of the naturally yellow but is much briefer than it was in its natural condition. The X-ray luminescence and the cathode phosphorescence were not destroyed by heating, so that concerning these, especially the X-ray luminescence, the question was not concerning the fact of luminescence but whether the readiness and brilliancy with which they responded had in any way been changed. I had no cathode ray with which to test these samples after radiation.

The color of these calcites in their natural condition, the yellow color at least, and their luminescent qualities, are not immediately dependent upon their composition, but upon some arrangement within the atoms constituting essentially different atoms. These changes may be facilitated by the presence of some extraneous atoms and perhaps retarded by others. I have in mind an explanation something of this sort—the action of the radium radiation may be facilitated by the presence of the rare earths, zinc or manganese, and retarded by the presence of magnesium, or contrary-wise. Two atoms of different kinds, or two different groups of electrons, that make up the atoms, may participate in these changes or they may not, as the case may be. The simplest cases that I know of is the transformation of colorless quartz into smoky quartz, and of colorless diamonds into greenish yellow or yellow diamonds; in the former case we have only two atoms or groups of electrons, in the latter we have only one, in which case it is certainly an intra-atomic change and it is probably the same in all other cases in which atoms of the same kind, or even of different kinds participate. The change may not be understood but it is probable that in the ordinary stable atom the electrical elements, protons with their accompanying electrons, have definite arrangements and the electrons definite directions of rotation. When the radium radiations enter this system, there is a disturbance and a new arrangement of matters which is accompanied by the emission of light and a change of color, in fact we have a modified atom. When the radium radiations cease, the electrons do not go back to their original positions or planes of rotation, but remain in new positions in which they continue, but these positions are not stable ones, they may be easily disturbed; still there is a tendency to persist in these new positions so that if only slightly disturbed they quickly resume their former position accompanied by the emission of light when the disturbing agent is removed. If the action of the exciting agent be too violent a permanent deformation is produced; namely, some, or all of those arrangements sensitive to the given agent, may return to the original, perhaps most stable position, when this reaction will no longer be produced. To be specific, our yellow calcite shows the following properties: A triboluminescence, a thermoluminescence at 60-180°C, a thermophosphorescence at 60-180°C, a photophosphorescense, a second thermoluminescence at 300°-400°C, an X-ray phosphorescence, an X-ray luminescence and a cathodic phosphorescence.

We have both a luminescence and a phosphorescence at temperatures between 60-180° C. These are dependent upon different arrangements of the protons with their electrons as units, or of the orbits of the electrons revolving about them. These are very sensitive, i. e. unstable arrangements which when sufficiently disturbed make their disturbance evident by the emission of light. If we keep up this disturbance in the case of thermophosphorescence for about 8 hours by maintaining a temperature of 155° C., this arrangement in the atom is destroyed; if we maintain this temperature for 36 hours, the arrangement on which the thermoluminescence was conditioned is destroyed. In the meantime, the property of photophosphorescence is growing weaker and weaker, the mineral is showing fatigue, and the color is growing fainter, in 46 hours it is dead. The intra-atomic arrangement on which this property and color depended has been converted into so stable a one that neither sunshine nor a temperature of 180°

C. will cause it to produce in us a sensation of light. This does not exhaust the arrangements actually existing in the atoms for if we heat the mineral, no longer responsive to a temperature of 180° C., or to sunlight, to 300 to 400° C., it again luminesces, in some cases, very brightly for various lengths of time, in my own experience up to 2½ hours, when it is colorless and dead except to the X-ray, radium radiation, and the cathode ray. The response to these seem to be indestructible and depend upon disturbances of what, for want of a better expression I will call the fundamental arrangement of the constituents of the atom itself.

An interesting question suggests itself—are the arrangements of the protons as such, or of the electrons revolving about them, so firmly fixed in those samples that have been killed by heating them to 400° C., 600° C., or 800° C., that they cannot be quickened again? This is what the radium emanation did, it caused these arrangements of the electrons to be made again and the yellow color was reestablished, also the thermo and photophosphorescent properties, and we can repeat the process. We did not succeed in reproducing the purple in the calcite but the purple is produced in glass. The similarities between the purple calcite and the purple glass are very suggestive.

The preceding facts, together with the further one that some calcites cannot be made responsive to sunshine by radiation while others can, does not throw much light upon the part played by composition. The one analyzed contained in addition to the calcic carbonate, iron, copper, magnesium and manganese. This would appear to exclude the atoms of lime, carbon, copper, magnesium and manganese from which we might infer that the rare earths were the sensitizing elements, but we have three specimens in which there are no rare earths, two of which are responsive to sunshine and the third one not. This third one is very sensitive to the action of radium emanation responding very brightly and persistently, and is rendered thereby responsive to sunshine. On the other hand, we have a yellowish calcite responsive to sunshine and containing rare earths, also small quantities of iron, copper, zinc, manganese, magnesium as oxids, and some phosphoric acid, which does not luminesce in the radium emanation and its responsiveness, to sunshine is not increased. These results are so at variance with one another that they cannot be harmonized so as to explain the view that these phenomena depend upon the composition whatever the form of the molecule may be. I have claimed that it is due to some intra-atomic arrangement of the electrical elements.

An interesting experiment in this connection was made with burnt lime. The burnt lime luminesced under the alpha rays, when hydrated it did not; with the gamma rays, it luminesced satisfactorily, but the hydrate was nearly a blank. With beta and gamma rays the burnt lime phosphoresced, the hydrate luminesced faintly but after heating on a platinum foil it luminesced but not so strongly as the lime from which it had been made. This would seem to indicate that the act of hydration had effected a change in the calcium atoms, or that the molecular structure may play an important part.

The deportment of phosphorescent substances toward the ultra-violet rays may also be affected by the absorption of moisture. Dr. W. S. Andrews in describing "Fluorescent and Phosphorescent Cadmium Sulfate" says: "When properly prepared, it shows a pink fluorescence under the iron spark and a bright yellow phosphorescence which is fairly persistent. Under cathode rays it shows a bright yellow fluorescence and phosphorescence, but X-rays produce no luminescence. If kept in the open it gradually absorbs moisture and loses its property of fluorescence which, however, can be restored by calcination." The American Mineralogist, Vol. 7, Feb. 1922, p. 22.

The questions presented by this problem are by no means solved. Why should calcites not all act alike? There are some calcites that are not responsive to sunshine and not at all, or only feebly, responsive to heat, but radiation renders them responsive to both agents; there are other calcites in which radiation produces no change.

If the yellow color and the luminescent properties can be restored to samples in which they have been destroyed, and if this color and these properties can be produced by radiation in samples that do not naturally possess them, are we justified in inferring that radiation produced this color and these properties in the caves and quarries where we find the samples. The yellow color must not be insisted upon to the extent of excluding color must not be insisted upon to the extent of excluding colorless samples, for we have cases in which radiation produced responsiveness without coloration and we also find colorless calcites that are responsive. In the experimental cases in which responsiveness without coloration was produced it seemed to be a question of the range of radiation.

Some luminescent phenomena are attributed to impurities in the substance. Our purest calcite is a responsive one, and others with a wide range of impurities are not responsive to sunshine, but we can make them responsive by radiation.

Some substances are responsive to both sunshine and the ultra-violet light of the iron spark, for instance, the fused cadmic phosphate, which would indicate differences in the intra-atomic structure and different luminescent phenomena.

This latter case is more complex than the simple statement just made might lead you to infer. It seems that there are two conditions in this case which must be very sharply distinguished. In the melt that Dr. Andrews sent me, there were two distinct portions, one strongly crystalline and the other glassy, which had beeen chilled by contact with the aluminium plate on which it had been poured. The crystalline portion is not responsive to sunshine, whereas the amorphous portion responds strongly with a white light that continues for at least 45 minutes. Dr. Andrews varied his treatment of this fused mass in that he fused two portions and allowed one to cool slowly without pouring, and the other, while very hot he poured into cold water. The slowly cooled, crystallized mass was responsive to both the ultra-violet light of the iron spark and to the cathode ray. The chilled portion was not responsive to either (Dr. Andrews). The deportment toward sunshine is exactly reversed. The crystallized mass, whether powdered or not, does not respond, whereas the amorphous or chilled mass does respond as stated above.

We have found some samples of glass petri-dishes*, that probably owe their responsiveness to sunshine and to the light of the molybdenum arc, to a similar fact, namely, that the glass was very hot when poured into the molds. We tried a Giessler's tube, the uranium glass and the body of the tube did not phosphoresce, but one end of the tube did. These facts point to the structure as influenced by the quick cooling of the very hot mass and the arresting of the intra-atomic motions as the cause of this responsiveness. Other petri-dishes and ordinary glass are just as truly amorphous, but they are not responsive.

We have so far given no consideration to the exciting causes, some of which are certainly constant—a given temperature, the light of the molybdenum arc, or of burning magnesium in the atmosphere, or the X-ray—and the sunshine in a given locality would seem to be pretty constant, but this is an open question, even when we have a cloudless sky.

You would certainly consider the sunshine at Fort Collins, located as it is in an agricultural section, on the plains a little way from the foot-hills, with a population of about 10,000 and with no factories to pollute the atmosphere except the sugar factory, which makes a campaign of not more than 120 days, as nearly constant in character as one would be likely to find anywhere, but how constant it actually is, is a question.

The deportment of the Ingleside samples, for instance, indicates that it is variable. Samples of this material were insolated on September 30, 1922, and though exposed to a clear sunshine for more than an hour failed to respond, nor did other tests give any better results. On July 24, 1923, and on a number of other dates, it responded briefly with a white light. On October 20, 21 and 22, the same pieces that had previously responded failed to do so. There is no question regarding the identity of the samples used, and the questions of composition, color, atomic structure, etc., are eliminated, and the failure must be attributed to a lack of effectiveness in the sunshine in exciting this particular material which is less sensitive than some others, for others were used as checks and these responded brightly.

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*Am. Jr. Sci., Vol. V, Apr., 1923, p. 315.

This is a rough test of the quality of the sunshine, still it shows clearly that this varies in its efficiency.

SUMMARY

Yellow Joplin calcites exhibit eight distinct luminescent phenomena—thermo-photo, X-ray and cathodic phosphorescence, tribo, two phases of thermo and an X-ray luminescence.

The purple Joplin calcite exhibits cathodic phosphorescence and no other, but luminesces very strongly at about 300 deg. C.

There are colorless calcites that possess the property of photophosphorescence but most of the calcites that possess this property have a yellow or yellowish color.

It is generally assumed that substances exhibiting phosphorescent properties under the excitation of certain agents owe it to certain impurities.

The impurities most frequently considered are manganese and dydymic oxids.

These calcites contain as the range of their impurities the ceric and yttric groups of the rare earths, copper, manganese, iron, chromium, alumina, nickel and zinc as oxids, occasionally sulfuric and phosphoric acid, also chlorin and sodium.

No correlation could be found between the presence of these and the phosphorescent properties. The properties may be present in the absence of these impurities or absent in samples in which they are most largely present.

Very many calcites show thermoluminesence at some temperature, some of them two phases of it, that is at different temperatures, but none equal to the purple one from Joplin, Mo., which shows no phosphorescence, except cathodic, though it has greatest abundance and range of impurities of any of the seventeen samples analyzed.

The color of both the yellow and purple can be discharged at temperatures below that at which calcic carbonate begins to decompose with the destruction of most of their properties.

This seems to correlate the property of phosphorescence with the yellow color and the purple with this high degree of luminescence, but colorless calcites phosphoresce and most calcites luminesce in some degree. Some colorless ones luminesce brightly and persistently.

The yellow and purple colors cannot be due to chemical compounds in the ordinary use of this term as is meant when we say that the chromates are yellow.

Radiation, either penetrative or by emanation, restores the yellow to samples from which this color has been discharged by heating them; it also restores the properties of photophosphorescence and thermoluminescence.

If colorless samples which have been prepared by heating purple ones be radiated, the purple color is not restored but they are converted into yellow calcites with the properties of yellow calcites.

If a purple calcite be placed in the radium radiation, the purple color is destroyed and the sample is converted into a yellow one with the properties of a yellow one, but the property of a long enduring thermoluminescence may not be wholly obliterated, i. e., it will be shortened but may not be so brief as in the naturally yellow one.

Colorless calcites that show these properties are changed into yellow ones and these properties are enhanced.

These changes wrought by radium emanation is often, but not always, accompanied by the emission of light, i. e., the samples luminesce in the emanation. The yellow color may be produced in colorless samples without the appearance of this luminescence.

There are some calcites that are negative in all of these manipulations; this means that even radium emanation is without effect upon them.

All samples that I have tested respond to the X-ray with a luminescence and to the cathode ray with a phosphorescence.

These properties, together with the yellow color, are due to atomic structure rather than to composition as the term is usually understood.

These properties can be produced and the yellow color established by radiation.

In cases of neutrality, of which we have found but three, we conceive the atomic structure to be one of extraordinary stability. It is not due to the absence of impurities for such are present.

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